EVALUATION OF THE EFFECTIVENESS OF WET BLAST CLEANING METHODS OF SURFACE PREPARATION

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FOREWORD

This research proj ect was Perf ormed under the National Shipbuilding Program. The project, as part of this program, is a cooperative cost-shared effort be tween the Maritime Administration and Avondale Shipyards, Inc. The work was also sponsored by the Federel Highway Administration and the U.S. Army Corps of Engineers. The study was performed by Steel. Structures Painting Council by subcontract from Avondale Shipyards. The overall objective of the pogram is to improve productivity and to reduce shipbuilding costs to meet the goals of the Merchant Marine Act of 1970. The studies have followed closely the pr oj ect outline approved by the Society of Naval Architects and Marine Engineers (SNAME) Ship Production Committee.

Dr. Bernard R. Appleman" and Dr. Joseph A. Bruno, Jr. of the Steel Structures Painting Council served as Principal Investigators for the research proj ect. On behalf of Avondale Shipyards, Inc. , Mr. John Peart was the Research and Development Program Manager responsible for technical direction and publication of the f inal report. Technical guidance and assistance to the project was also provided by Dr. Lloyd M. Smith of Federal Highway Administration, and Mr. Al. Beitelman of U.S. Army Corps of Engineers Construction Engineering Research Laboratories.

Also, we wish to acknowledge the support of Mr. Robert Schaffran and Mr. Joel Richards of the Maritime Administration, and Mr. John M. Hooks of the Fe Feder al Highway Administration. Special recognition is given to SSPC staff members Ki tti Condif f, Aimee Beggs, and Harold Hewer, end to 14. John D. Keane, former Executive Director.

A list of the cooper sting companies and individuals is given in Appendix D.

EXECUTIVE SUMMARY

Dry abrasive blasting, the most efficient and econamical technique for preparing steel for painting, is frequently not feasible or permitted for one or more of the following reasons: contamination of machinery or equipment, damage of ad j ascent intact paints, or visual dust pollution. The use of sand may present a hazard from silica dust inhalation. Currently, the most practical and widely used alternatives to dry blasting are wet methods of blast cleaning. The use of water in combination with abrasives significantly reduces the amount of dust Produced and the range ov er which it is distributed. Wet methods of blast cleaning also reduce the visible pollution from abrasive dust c1 ouds.

This report describes the results of field evaluations of several differ ent types and manufacturers of equipment for wet blasting. The objectives of this study are as follows:

- o Determine cleaning rates and effectiveness of wet blast units
- o De termine safety, reliability, and practicability of wet blast units
- o Develop guidelines for use of wet blast equipment for cleaning' various types of structural. steel. for repainting

Fran a review of trade and technical literature and public requests for information, about 10 different wet blast units were selected for field evaluation. These ev aluations were conducted on steel surfaces typically encounter ed in marine, highway and water works maintenance, such as rusted and pitted steel, millscale covered st eel, and painted steel.. For each demonstrate on, the representative surfaces were cleaned using both wet and dry blast cleaning techniques with careful documentation of cleaning rates, cleanliness and other important factors. The principal conclusions of this work were as follows:

- o Dry sandblasting is ov erall faster and more effective than any of the wet blasting techniques.
- o Incorporation of water into air abrasive bl asting produced cleaning rates up to 80-90% of those of dry blasting, and proved very practical for field applications.

o Incorporation of abrasives into a mediun to high pressure water blast (6-20 ,000 psi) gave cleaning rates which were only one half or less those of dry blasting. Moreover, because of the high thrust of these units, they have limited applicability for extended field use as hand held units.

o Certain low pressure (3-4,000 psi) water blasters with abrasive addition have demonstrated the ability to remove rust, paint, and millscale with little operator fatigue. The cleaning rates however, are considerably lower than conventional dry blasting.

o High pressure water iii. blasting without sand is not capable of removing tight rust and mill scale under normal conditions.

o All the wet blast units observed produced a significant reduction in the dust.

o The units observed varied ed consider ably in cost, portability, production capability, and adaptability to existing blast cleaning equipment. The specific unit to be chosen depends on the size end the type fo job and availability of support equipment.

o The nature of the substrate end the type of abrasive used has a significant effect on the cl caning rate.

o When wet blasting, inhibitors are frequently necessary to prevent flash rusting. Several types were proven to be effective in controlling flash rusting for at least several hours.

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SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

This report has described various classes and types of wet blasting equipment for cleaning structural steel for painting. There is no single piece of equipment that is appropriate or recommended for all types of cleaning. The discussion to follow summarizes the major advantages and disadvantages of the types of units investigated. It is to be noted that our field evaluations considered only a snail number of the units avail able; and in several demonstrations only small areas were cleaned. The aim was to evaluate the major representative types in each of the three broad categories described in Section 3. However, there may be other units available which will off offer features and achieve cleaning rates that are better (or worse) than described. Ther efor e, following this discussion we present some general. user guidelines regarding what to look for in considering the use or purchase of wet blasting equipment. In addition, there is a user checklist which itemizes the type of information a user should ascertain about his particular requirements for wet blasting.

1.1 ADVANTAGE, LIMITATIONS. AND RECOMMENDED USES FOR WET BLAST UNITS

A summary of the advantages and disadvantages of the various wet abrasive blasting equipment units is presented in Table I.

1 .1.1 Air Abrasive Wet B1asting

These units closely resemble existing air dry abrasive blasting in their operation and use. The cleaning rates approach those for dry blasting (approximately 80-90%). The dry blast operator would have little difficulty adapting to this type of equipment; however the incorporation of water into the abrasive stream does affect the visibility of the operation and the manageability of the nozzle. Safety features such as the deadman control switch may differ in their operation or maintenance when using wet sand. Clean-up is different from that of dry blasting, as it requires a spray of pure water rather than dry air; dry compressed sir will normally not remove wet sand frcm a surface. To increase the drying rate, the rinse may be followed by blowing with dry compressed air.

This cleaning method usually requires use of inhibitors in the water to prevent flash rusting. These units generally have provision for adding inhibitor to the water stream, but the addition of inhibitor should be metered so that: there is a constant, adequate concentration of inhibitor.

TABLE I

ADVANTAGES AND DISADVANTAGES OF
WET BLAST UNITS

TYPE OF UNIT	ADVANVANTAGES	.DIS ADVANTAGES
Air Abrasive Wet Blasting	High Cleaning Rates Operation Similar to Dry Blasting Reduced Dust Reduced Sand Bounce Back Can Be Retrofitted to Existing Dry Blast Unit Low Water Flow Rate	Requires Extra Hose to Nozzle Sludge Clean-up
Air/Water/Abrasive "Slurry" Blasting	High Cl caning Rates Many Nozzles From Control Unit Inhibitor Automatically Metered Low Water Flow Rate Greatly Reduced Dust Suitable for Feathering Paints Well Suited to Large Production Jobs	Relatively High cost Separate Operator for Control Unit Sludge Cl ean-up
High Pressure Water Abrasive Blasting	Greatly Reduced Dust Long Hose Lengths Possible Low Abrasive Consumption Extensive Manufacturer Experience	High Operator Thrust Reduced Cleaning Rates Poor Visibility Greater Fatigue High Water Flow Rate Relatively High Cost
Low Pressure Water Abrasive Blasting	Maneuverable and Portable Relatively Low Cost Low Abrasive Consumption L Low Operator Thrust	Low Cleaning Rates Short Hose Lengths
Ultra-High Pressure Water Jetting	No Abrasive Cl Clean-up Simpler Design and Maintenance	Does Not Remove Mill Scale No Surface Prof file High Water Consumption Poor Visibility Relatively High Cost High Operator Thrust Operator Fatigue

Alternatively, it is possible to use inhibitor only in the rinse and not in the ge ner al. blasting. This may require additional control on the addition of inhibitors.

Because of their similarity to dry blasting, these units can be used as direct replacements for ,dry blast units. The retrofit types have attachments which fit onto an. existing dry blast unit. One can upgrade a dry blast unit to an air abrasive wet blast unit and still use the same compressor, sand pot and nozzles. This is considered the easiest and most inexpensive way to attain wet blasting capability.

Air abrasive wet blast equipment is also sold as complete units. This option would be suitable for those considering purchasing new units or for contract who would like to undertake wet abrasive blasting. These units have the advantage of being an integrated system with all parts and components from one source. This could improve the ability to get servicing of the equipment. Because the unit is integrated, it may be easier to transport than a system made up of individual components. This type of unit is considered very well suited for most blast cleaning operations that are being done with dry abrasive blasting.

1.1.2 Air/Water/Abrasive Slurry Blasting

These units use compressed air as the medium to propel the eroding material. They differ from air abrasive wet blast units in that the abrasive is mixed with the water at a control unit located up to 50 feet upstream of the nozzle. This permits a more intimate mixing of sand and water, which is claimed to give be tter control of dust and to improve the ability of the slurry to selectively remove topcoats and to feather paint. These units are designed for high production work and are frequently operated at lower pr essures than conventional. dry blasting. Typically they have several nozzles and hoses connected to a single control. Because they have sophisticated means of adding inhibitor and for communicating and controlling the various components, these units are more expensive than air abrasive wet blasting units. They are perhaps more suited to a maintenance contractor who participates in a number fo large jobs, rather than for maintenance crews at a facility. The latter may be better off purchasing a few small units, which would allow more versatility in cleaning various areas of a plant or different structures.

1.1.3 High Pressure Water Abrasive Blasting

These units typically operate at pressures up to about 10,000 psi and flow rates of 8 to 10 gallons per minute (GPM). A major feature is the high operator thrust, typically 35 to 50 lbs, which greatly limits the amount of continuous work that can be attained with a hand held unit. Moreover, the cleaning rates obtained with these units are considerably less than dry blasting, approximately in the range of 30-50%, for producing near-white metal. The rates depend strongly on the type of surface being cl cleaned. These units are best suited for removing loose rust, and paint. Because of the large volume of water required, the cost of inhibitor for this type of unit could be considerable, unless the inhibitor is used only for the rinsing operation. This type of unit is suitable for cleaning to SSPC-SP 10 l However, some type of automated control of the blasting head would be required to eliminate the large variability resulting from manual control of the high thrust. Another possible adaptation for this type of equipment is to use multiple nozzles at lower flow rates. This arragement would reduce the operator thrust by "a factor of 2 (f or 2 nozzles) and probably result in an increased cleaning rate per volume of water because of greater degree of operator control. Again, the rate of cleaning surfaces to bare metel would be relatively slow, but for maintenance painting where only spot removal to bare metal is required this method would be relatively rapid.

1.1.4 Low Pressure Water Abrasive Blasting

This type of unit offers a relatively inexpensive method for surface preparation of steel for painting. Because of the low presures, (2,000-4,000 psi) , the cleaning rates are considerably less than dry blasting. These low pressures and flow rates al so resullt in very much reduced operator thrust. These units are suited for removing old paint and loose rust with a minimum of loose sand and dust. They are portable end best suited for small jobs. As with the other types, inhibitor is normally required in the water to prevent flash rusting.

1 .1.5 Ultra-High Pressure Water Jetting

Water pressures of 20,000 psi or greater without sand are capable of removing tight paint and most rust, but not tight mill scale. In addition, they will not produce a surface profile. The cleaning path is quite narrow for the most erosive cleaning. A broader path can be attained using a fan jet, which results in a reduced intensity of the jetting action. These units are suitable for preparing surf aces for repainting in which it is not necessary to clean down to tare metel for most of the surface. (They are much slower than the other units in cleaning down to bare metal.) Their primary advantage would be in situations where abrasives cannot be tolerated, thus they could be used around some sensitive equipment or machinery, or where it would be extremely difficult to clean up sand or sludge. They are also reportedly capable of removing the water soluble contaminants from badly corroded steel., This could be an added advantage if it is verified for specific conditions.

1 . 2 INFORMATION FURNISHED BY USER

In order to select the most appropriate unit for a given type of operation, the user should clearly identify al1 the requirements of the job. The major factors are listed in Table II.

TABLE II

CHECKLIST FOR SURFACE PREPARATION REQUIREMENTS

Type of Job:	Multi- year continuous use ____ Specific job(s) __
Scope of Job:	Total area to be cleaned ____
Type of Steel:	Large flat areas (e.g. tank, plates, ship hull) ____% Intricate shapes (e.g. truss bridge, pipe rack) ____%
Location and Accessibility:	Concentrated in small area (large structure) ____ Scattered (small structures in district) ___ Extensive rigging for elevated work _____ Mostly ground work, easy access ___
Utilities and Support Equipment:	Water supply availability ______ Capacity (gpm)______ Proximity of electric power _____ amps/volts _____ Diesel or electric engines ______ hp______ Pump: Type____ Max. Pressure ______ Volume ______ Air Compressor: Type ________________ CFM ________________ Blast MACHINE: Type ________________ Capacity ____________
Condition of Steel:	New steel. mill scale - A B C ________ (SSPC-Vis 1) Old steel - intact coating _____ mild corrosion____ Old steel - badly rusted ___ pitted___ contaminated_____
Type of cleaning Required:	Blast Clean___ SSPC-SP 6 ___ SSPC-SP 10 ___ Retain tight rust and paint____ Spot blast and repair___
Regulatory Restrictions:	Environmental - gener al dust ___ Environmental - specific limitations on: particulates____ visibility___ paint waste Spent abrasives disposal: general ____ toxic materials____ Mat Materials ____
Other Restrictions:	Sensitive machinery or equipment nearby____ Avoid damaging/contaminating other surfaces ____ Special dif ficulty in removing: sand ____ water____ sludge_____
Type of Laborers:	In-house crews____ Out side contract or: specific job only ____ Wet blast experience: none____ on the job_____

1.3 ADDITIONAL WORk

There are three major areas in which additional research and development work is needed to provide users of wet blasting equipment with improved confidence and performance. These areas are: the effect of inhibitors, the effect of contaminants on steel, and user guides.

1 .3.1 Effect of Inhibitors

There is an urgent need for additional research and evaluation on the effect of inhibitors in preventing flash rusting and upon the performance of paints. Controlled experiments are needed in which different inhibitors are applied at different levels to steal. for various control periods and in various humidities to evaluate their ability to prevent flash rusting. Another variable should be the history of the steel prior to cleaning (i.e. extent of of previous contemination) . In addition, evaluations of paint systems applied over the inhibitors, again varying the concentrations, types of inhibitor, and the time period of painting are needed. The evaluations should include paints that are designed to go over wet surfaces (and reportedly not requiring inhibitor) as well as zinc-rich, epoxies, and other conventional maintenance paints. A combination of accelerated tests and long-term exposures is required.

1 .3.2 Effect of Removing Non-Visible Contaminants

There have been numerous claims in the literature that the presences of chlorides, sulfates, end other non-visible contaminants on blast cleaned steel greatly diminishes the paint life. It is also claimed that the wet blast cleaning techniques are more effective than dry blasting in removing these contaminants. Research and evaluations are needed to determine how and at what level these contaminants affect paint life, and secondly, how do these various cleaning techniques (both wet and dry) compare in their ability to remove these contaminants.

1 .3.3 Guides for Wet Blast Ceaning

There is available a great deal of information on the use and operation of wet blast units. It is recommended that these be consolidated in the form of user guides. In particular, these guides should cover the major or operating parameters, the selection of units, and safety of both air abrasive wet blasting techniques and pressurized water abrasive blasting. There is some ongoing activity in both of these areas. The SSPC Task Group on Wet Abrasive Blasting (part of the committee on surface preparation) is developing two user guides:

- SSPC Guide to Water Blasting With and Without Abrasives
- SSPC Draft Guideline on Air/Water/A brasive Blast Cleaning

These guides are expected to be issued in 1986. In addition, the U.S. Water Jetting Technology. Association is preparing a guide for the operation of high pressure water jetting equipment. This will include sections on safety, as well as other operting parameters. The guide is expected to be issued in 1985. A similar guide has been prepared by the Association of High Pressure Water Jetting Contractors, (an English group). Their document is referred to as a "Code of Practice".

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SECTION 2

BACKGROUND: THE NEED

It is universally acknowledged that dry abrasive blasting is the most efficient and economical technique for cl caning structural steel for painting in industrial applications. The abrasives blasting unit delivers to the surface a high velocity stream of hard, angular abrasive, which has the ability to rapidly remove existing paints, rust, mill scale. and, and to roughen the base metal for improved paint adhesion. The quipment and techniques for dry blasting have be come standardized to a high degree and provide a high degree of reliability and uniformity.

Dry sand blasting has been restricted in recent years because of health hazards from silica dust inhalation, sir quality concerns with visibility, expended particul ates, and fugitive or nuisance dust, and dust contamination of machinery or equipment. There has al so been concern about the disposition of the spent abrasive, used to remove paint films which may contain lead compounds or other toxic materials from the paint film.

Health off icials and the protective coatings industry have recognized the serious problems caused by inhaling dust from silica sand abrasives. This can cause a debilitating lung disorder known as silicosis. The Occupational Safety and Heal the Administration (OSHA) has established limitations on the average level of silica that a worker may be exposed to during an 8-hour period. This limit depends on the amount of silica in the abrasive, as shown in Table III. However for most conditions of open air blasting, the blaster would be exposed to levels of silica higher than this limit, and therefore an air-fed respirator is required. This equipment is standard in most blasting operations today. Frequently, however, the dust travels well beyond the immediate vicinity of the blasting and provision must be made to monitor the dust level in areas where other workers may enter.

Several states also have regulations regarding the obstructions to visibility caused by dust clouds. For example, California requires that the dust plune be no darker than No. 1 on the Ringelman Chart (published by the U.S. Bureau of Mines) for more than 3 minutes in any one hour. Pennsylvania has a similar requirement based on 20% obstruction. Certain types of silica sand will indeed produce dust levels greater than these. Many states also have provisions (laws, regulations, etc.) that could be used to restrict abrasive blasting because of fugitive dust (high localized co ncern trations of dust) or as a ge neral nuisance. Abrasive dust fallout, for example, could be considered as a nuisance to nearby parking lots, boats, or structures.

TABLE III

REGULATIONS AFFECTING ABRASIVE BLASTING

Regulated Item	Regulatory Agency	Summary of Regulation
Silica (respirable)[a] (8 hour average)	OSHA	Max. of 10 / (% SiO_2 + 2) mg/m^3
silica (total dust)a (8 hour average)	OSHA	Max. of 30 / (% SiO_2 + 2) mg/m^3
Inert Dust (respirable)a (8 hour average)	OSHA	Maximum of 5 mg/m3
Inert Dust (total dust)a (8 hour average)	OSHA	Maximum of 15 mg/m3
Particulate Matterb (24 hour average)	EPA	Maximum of 260 microgram/m3
Visible Emissions	State & Local	Example: (PA) Maximum of 20% opacity reduction for 3 minutes an hour
"Nui sance "c	State & Local	Example: (VT) "not discharge. . . air contaminants which will cause . . . detrimental nuisance or annoyance
Fugitive Dust d	State & Local.	Example: (CA) Maximum of 100 ug/m^3 excess of upwind over downwind

a - Code of Federal Regulations (CFR): 29 CFR 1910
b - 40 CFR 50:6.7
c - Bibliography: Reference 10
d - Bibliography: Reference 12

The Environmental Protection Agency (EPA) has established limits on the total permissible concentration of suspended particulate in air. Proposed restrictions by EPA would apply primarily to particulates with a diameter of less than 10 microns. Paint parti cl es removed from the surface could result in an operation exceeding the permissible levels. Another potential problem is the disposal. of the spent abrasives which may contain lead or other toxic materials. These materials may come under the jurisdiction of EPA hazardous waste disposal provisions, or require that an EPA extraction procedure be run to determine the concentration of leachable toxic materials. The most significant restrictions are summarized in Table III. It should be noted that several of these would also apply to non-silica abrasives. Alternatives to sand blasting include silica-free or

1ow-dusting abrasives, high pressure water blssting, wet sand blasting, power tool cleaning, and chemical cleaning. Alternative abrasives such as mineral slags often eliminate the silica hazard, but these abrasives may be more expensive or difficult to obtain than sand, and have recently been under attack for some trace concentrations of toxic heavy metals. High pressure water blasting and hand and power tool cleaning are suitable for removing loose rust and paint, but cannot remove tight mill scale, tight rust, and paint. Other new techniques have been developed, but have not yet proven practical for large scale production cleaning of steel. Wet abrasive blasting offers the potential to reduce or eliminate many of the problems associated with dry blasting, end at the same time, offer relatively high production rates and c1eaning efficiency.

Wet blast units can be categorized into four major types, as shown in Table IV. Over the last 10 to 20 years a large number of different types of systems of each of these three have become available. There are large differences among the types of wet blasting equipment in operating Parameters, reliability, cleaning rates and effactiveness, cost, safety, and user satisfaction. In addition, new and improved versions are continually being developed, promoted, and evaluated for various and sundry applications. Thus, a need exists for an objective evaluation of the key factors and parameters in wet blasting equipment and an evaluation of the relative merits of commercially available techniques. In response to this need, the U.S. Maritime Administration, in cooperation with tie Federal Highway Administration and the U.S. Army Corps of Engineers have sponsored the present study, with the following objectives:

- o Determine Gleaning rates and effectiveness of wet blast units
- o Determine safety and reliability of wet blast units
- o Develop guidelines for use of wet blast equipment for cleaning various types of structural steal. for repainting

TABLE IV

CLASSIFICATION OF WET BLASTING UNITS

Air Abrasive Wet Blasting

Air/Water/Abrasive Slurry Blasting

Pressurized Water Abrasive Blasting
- o High Pressure Water (6,000-15,000 psi)
- o Low Pressure Water (2,000 - 4,000 psi)

Ultra High Fressure Water Jetting (20,000-50 ,000 psi)

BACKGROUND: THE NEED

The enphasis of this study was to be upon field demonstrations rather than literature reviews or second-hand accounts. After reviewing the trade and technical literature, and responses from public requests for information, 10 different wet blast units were selected for field evaluation. These evaluations were conducted on steal. surfaces typically encountered in marine, highway and water works maintenance, such as rusted and pitted steel, mill scale covered steel., and painted steel. For each demonstration, the representative structures were cleaned using wet blast techniques and dry blast cleaning controls, with careful do cementation of cl caning rates, cleanliness, and other factors required for the evaluation. In addition, information was sought and revised on a large number of commercially available units and on cleaning rates and degree of cleaning obtained by other experiments.

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SECTION 3

DESCRIPTION OF UNITS AND TECHNOLOY

State-of-the- art protective coatings, designed to give long term service life in adverse environnents, require a substrate which is free of rust, mill scale, paint, and contaminants and has a surface profile to promote good adhesion. To achieve this condition, for both new steels and previously painted or corroded steels, requires a mechanical or other ercsion process to remove tie surface layers and expose the hare steel substrate. The erosion is usually achieved by propelling small abrasive particles onto the surf ace at high velocities -- by centrifugal wheels. or compressed air. The centrifugal wheel process utilizes recyclable abrasives such as metallic grit and shot. For field air abrasive blasting, recycling is normally not feasible, and a dispoable abrasive, e.g. silica sand, is usually used. Other abrasives such as mineral slags (e.g. , copper and coal slag), garnets, flints, walnut shells, and corn cobs have also been used because of the health problems associated with silica sands or because of special requirements.

The erosion of material from metallic surfaces can also be accomplished by other means of applying mechanical energy such as abrasive wheels, hardened needles, abrasive coated materials, and wire brushes. In addition, non-mechanical forces which have been used for cleaning steel. include chemical forces (e.g. acids, detergents, chelating complexes, solvents) , thermal forces (steam or flame) , and energy radiation (ultrasonic, microwave, laser, high-intensity light) .

Water has also been used in several forms for removing surface layers from steal.. Water can be used by itself or in combination with sbrasives or cleaning agents and cleans by a combination of mechanical force and by solubilizing or emulsifying contaminant materials.

Wet abrasive blasting can be divided into 2 broad categories, air abrasive blasting with water addition, and water blasting with abrasive addition. The sections to follow will describe the basic principles and the variations of these 2 type- of wet blasting. The discussion will also review tie most important parameters and features and components of these systems investigated.

DESCRIPTION OF UNITS AND TECHNOLOGY

3.1 AIR ABRASIVE BLASTING

A source of compressed air (e.g. 250 to 500 cubic foot per minute (CFM) compressor) propels abrasive particles from the abrasive hopper through tie blast hose to a venturi nozzle at 90-100 psi. This force is sufficient to remove hard rust, tight mill scale, and virtually all types of coatings that are applied to steel. It also has the capability of eroding some of the metal to poduce a roughened contour known as surface pro file. The rate of surface cleaning with sir blasting depends on the pressure at the nozzle, tie nozzle crifice, the size, shape and hardness of the abrasive, the configuration of the substrate, tie type coatimg or corrosion Poduct, The angle and standoff distance of the nozzle, and the skill of tie operator. The average depth and the shape or sharpness of the surface prof ile de psnd primarily on the size, hardness, and shape & tie abrasive and to a lesser extent on the angle or incidence of abrasive stream. These para.eters have been well documented in earlier publications. They are identified here in order to explain how the introduction of water can affect the rate and ef festiveness of the cleating. Essentially all of tie requirements for high quality, high production abrasive blast cleaning are valid also for air abrasive wet hlasting. Among the most important fact ors are:

- o Adequate size of compressor to ensure 90-100 psi at the nozzle.
- o Adequate nozzle size to enable productive cleaning (orifice disa+ ter of 3/8 inch cr larger usully recommended).
- O Hard, tiregularly shaped abrasive to cut into surface without excessive breakdown of abrasive.
- o FPoperly sized abrasive to produce the required surface profi

Other requirements for proper air blasting are available from equipment and abrasive manufacturers and from organizations such as SSPC and the National Association of Corrosion Engineers (NACE).

The cl caning rates achievable with air abrasive blasting are variable because of variations in the surface conditions, and the configurations and accessibility of structures. 'ihe data in Table V are based on trials mnducted on regularly shaped steel blast cleaned under controlled conditions. They are provided here top esent a reference wint for tie c1 caning rates observed in the wet blasting units of this stu~.

3.2 AIR ABRASIVE WET BLASTING

The sir abrasive wet blasting units vary with respect to nozzle design, the type & control system, the device for adding and monitoring inhibitor, and the configuration of the overall system. Water can be added to the abrasive stream well upstrem of the nozzle, just before entering the nozzle, or downstream of the nozzle. One of the earliest methods developed was the water envelopment process or Mater curtain method, "

TABLE V

TYPICAL CLEANING RATES FOR DRY SAND BLASTING[a]
(Sq. Ft./Hour)

		Initial Surf ace Condition[b]		
Final Surface	Nozzle Diameter (Inches)	Adherent Mill Scale (Rudhtsfrtgrade A)	Rusting Mill Scale (Rustgrade B)	Pitted Rusted (Rustgrade D)
Near White (SSPC-SP 1o)	1/4	95	110	65
	3/8	210	240	150
Commercial (SSPC-SP 6)	1/4	110	130	80
	3/8	250	290	180
Brush Off (SSPC-SP 7)	1/4	300	340	210
	3/8	670	770	480

a - Data derived from Industrial maintenance painting, 3rd Edition, P. E. Weaver, 1967, published w National Association of @rrotion Engineers, Houston, Texas.

b - Guide to Pictorial Surface Preparation Standards for Painting Steel Surfaces (SSPC - Vis 1), frOm Steel Structures Painting Manual, Volume 2: **"Systems and Specifications," 4th Edition, J.D. Keane, J.A. Bruno, Jr.,** and A.M. Levy 1985 published by Steel Structmes pinting ~~cil$ Pitsbur ttsburgh, , Pennsylvania.

which p?ojects a cone of water around the stream of air and abrasive as it leaves the nozzle. A simple water ring adaptor fits around the blasting hose nozzle as shown in Figure 3-1. This technique is reported to redue the airborne dust by about 50-75% (see Table C-1). It has a minimal effect on the cleaning rate because the water ties not mix with the abrasive. It does make the unit slightly more unwieldy and could affect cleaning rate in that manner.

The water stream could also be spray into the abrasive stream beyond the nozzle, as illustrated in Figure 3-2. This gives a greater degree of dust control than the water envevelope method because the abrasive is wet before it reaches the surface.

In the second type of air abrasive wet blasting, the water "is added to the abrasive just before it reaches the nozzle. one version, a nozzle adaptor is mounted between the nozzle holder and nozzle. Pressmized water from an air=operated pump is controlled with a needle valve, as shown in Figure 3-3. The water Wessure is normally on the crder of 30&800 psi. For many of these units, the water and sand can be operated independently. Thus, for example, by closing the medle valve, one ~n dry sandblast in areas where wet' blasting may not be reeded. Also, by releasing the nozzle control, one can use the low presswe water to wash cff the sand from the surface.

Figure 3-1 Water Ring Attached to Sand Blast Nozzle (Courtesy of Service Painting Company)

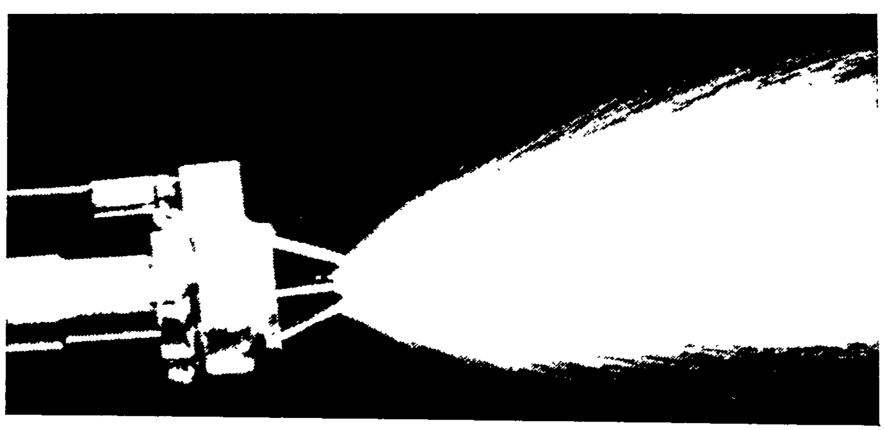


Figure 3-2 Conical Water Ring: Side View (Courtesy of Clemtex)

control, one can use the low pressure water to wash off the sand from the surface.

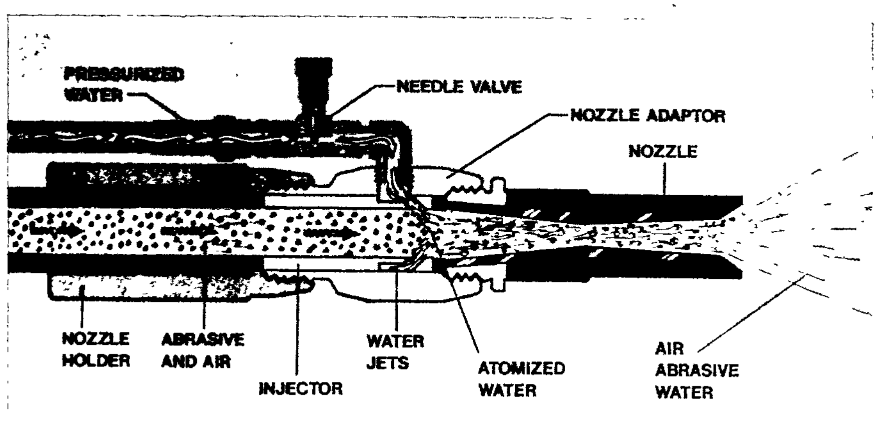


Figure 3-3 Nozzle for Air Abrasive Wet Blast (Courtesy of Clemco)

There are several types of control units for these systems. A simple small control unit, shown in Figure 3-4, consists of pump, pressure regulator filter, and oil lubricator. The compressed air requirement to drive the pump is about 30 CFM at 100 psi. A high-pressure hydraulic hose conveys the water from the pump to the nozzle. This unit is separate from the air compressor required for the abrasive blaster. This unit is thus designed as a retro-fit for existing abrasive blasting units.

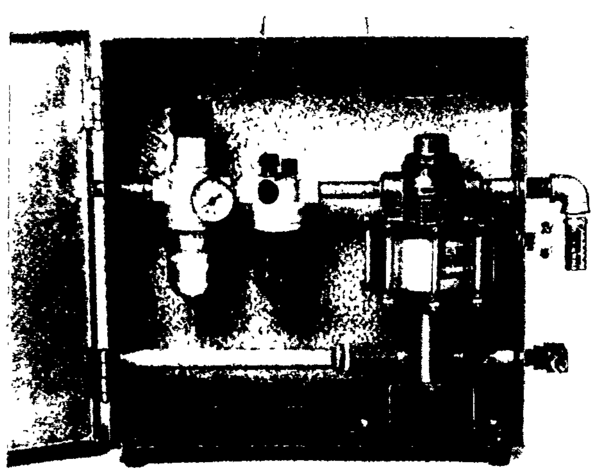


Figure 3-4 Control Unit for Retrofit Air Abrasive Wet Blast (Courtesy of Clemco)

Another sir abrasive wet blaster is sold as a complete unit, including abrasive blast machine, air powered pump, and a mixing tank (see Figure 3-5). This type of unit also allows independent "control of the abrasive or the water, which can both be controlled by the operator. The mixing tank allows inhibitor to be metered into the water to prevent flash rusting. These types of units are extrmely effective in reducing the amount of dust. Their relative effectiveness in c1eaning and the operation will be discussed in the following chapter.

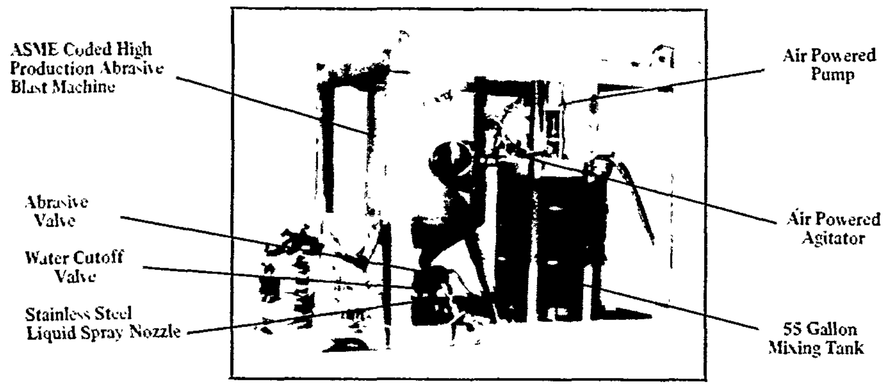


Figure 3-5 Control Unit for Air Abrasive Wet Blast: Ccmplete System (Courtesy of Clatex)

3.3 AIR/WATER/ABRASIVE SLURRY BLASTING

A third variation of this technique is addition of water to the abrasive stremn at the control unit upstream of the nozzle (see Figure 3-6). In these systems, the mixture of air, water, and sand is propelled through the hose to the nozzle without any additional coupling at the nozzle. In several of these units the air, water, and sand can be indepee dently controlled by the operator, either by microswitches at his control, or remotely, by another operator, who may be in audio contact with the blaster. As with the previous types of systems, these units allow the operator to rinse off the wet sand from the surface with water, often containing an inhibitor. In addition, several versions are capable of cutting off the sand flow and using compressed air to dry the surface after clean ing, or to blow away debris before blasting. These units vary with the amount of sand and water used. Certain units can be used to feather back paint by reducing the air pressure, resulting in a less erosive slurry stream. A schematic of the control system for one unit is shown in Figure 3-7. Figure 3-8 is a photograph of a control unit which has a capability of 3 operators from the same control system. This figure also illustrates the use of microswitches to control abrasive flow. The air/ water/sand systems normally are self-contained units, with a capability of 2 or more operators from a single control unit (see Figure 3-8). Because the sand is intimately mixed with the water, these units are also very effective in reducing the amount of dust.

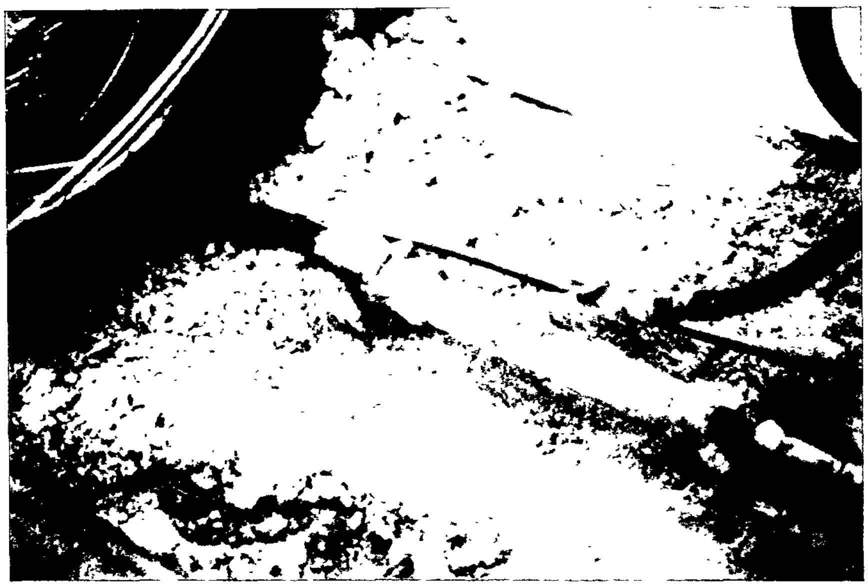


Figure 3-6 Water Abrasive Mixing Chamber in Slurry Blast Unit (Courtesy of Hydrair)

3.4 HIGH~H PRESSURE WATER BLASTING

High pressure water blasting is a technique which produces a high velocity stream of water by passing a flow of pressurized water through a specially designed small crifice nozzle. This jet has some erotive force and has been utilized for removing paints and corrosion products from structural steel. The Principal focus of this report is on water blasting with abrasives rather than on pure water blasting. However, a brief review of the principles of operation of water blasting is provided for an understanding of the operation of the water blasting with abrasives. For comparison purchases, several of the highh Pressure units were operated without abrasives. In addition, one which was designed to be operated without sand because of the extremely high pressures attained was observed.

The major components of a water blasting unit are as follows:

- Positive displacement pump and appropri ate power unit
- high pressure hydraulic delivery hose

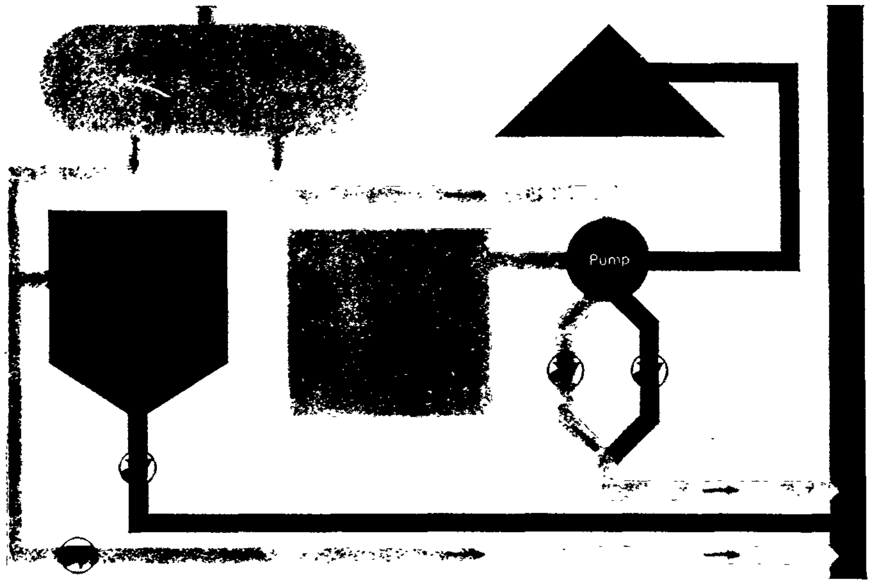


Figure 3-7 Schematic of Air/Water/Abrasive Slurry Unit (Courtesy cf Hydrair)

o high preessure nozzle

o control valve system

Other components include water filter, pressure gauge, flow meter, inhibitor, and metering and monitoring attachments.

High pessure water blasting utilizes water pressrues frcm 6,000-15,000 psi. There are machines which @n rrryoduce Tessures of 50,000 psi or greater, but these are primaril.y used in secialized applications such as rock cutting. Lower Wessure water jets with pressures in the 2,000-4,000 psi range are also considered in this study.

There are several pump designs that have been used to produce high pressure water. Two of the most important are the direct acting plunger pump, and the radial. piston diaphragm pump. The major differences among these pumps are the efficiency in producing pressurized water and their maintenance characteristics. The multi-cylinder, single-stage, radial piston diaphragm pump does not require piston seals. Another variation is a six-cylinder axial piston unit, which includes 2 chambers, and a short stroke design which significantly reduces pulsation.

The water gun should be of the "fail-safe" type, which relieves the pressure when the operator releases the trigger. Nozzles are usually circular orific's for concentrated round spray, and tapered or flat for fan

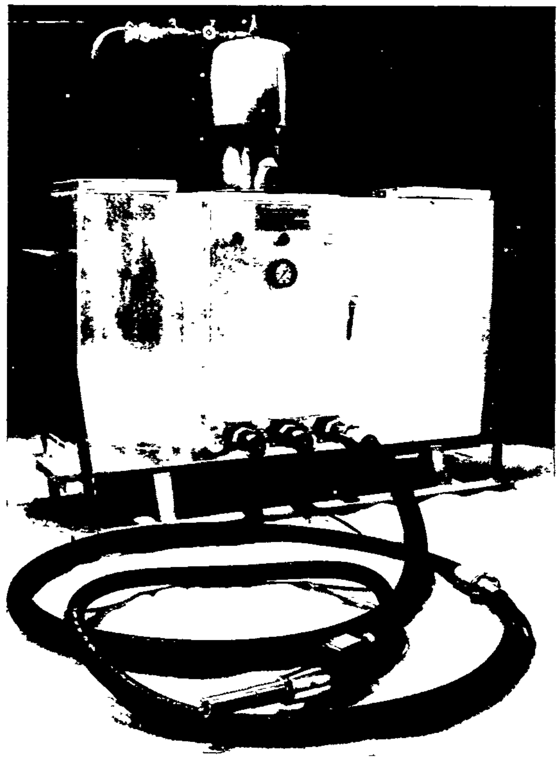


Figure 3-8 Control Unit for Air/Water/A abrasive Slurry Blast (Courtesy of Williams Contracting)

spray, which distributes the water in a larger pattern. Long hoses may be used (200-300 feet) without significant loss of pr essure.

3.5 OPERATOR BACK THRUST

An important consideration is the amount of thrust that the operator must withstand in using a high pressure water blaster, which depends on the Pressure, flow rate, and the nozzle orifice. It is noted that an operator thrust of greater than about 35 or 40 lbs can become very fatiguing after a relatively short priod of time. Thrusts above 50 lbs are extremely diffi-cult to control.

The back thrust can be eliminated by using a zero thrust gun. The available flow from the pump is split into a forward and rear jet that offsets the thrust or neutralizes the recoil. At a given pressure this will result in a halving of the flew rate available for cleaning.

The thrust of a high Pressure water jet can be computed from the pressure and the flow by the following equation:

Thrust (lbs) = 0.05 x Q(GPM) x P(psi)

where Q = flow rate in gallons of water per minute and
P = prssure

The flow rate for a given water pressure is determined by the nozzle orifice diameter. Thus, the thrust can also be approximated by F 1.4 P x d2 where d orifice (ii diameter in inches. One can also compute the tiecretical horsepower required to power a jet at a given pressure and flew rate. These quantities can be d etermined from the nomigraph given in Appendix C. Some calculated parameters are given in Table VI for high presswure jets.

TABLE VI
OPERATOR BACK THRUST WITH WATER JETS

Pressure (psi)	Flow Rate (GPM)	Orifice Diam. (inches)	Theoretical Horsepower	Thrust (lbs)
35,000	2	0.020	55	20
20,000	10	0.051	110	74
20,000	7	0.043	80	52
10,000	10	0.062	62	53
10,000	6	0.048	38	32
7,000	10	0.067	40	44
7,000	6	0.052	25	27
5,000	8	0.065	23	30
5,000	4	0.046	12	15
3,000	4	0.053	7	12

There are a large number of different types of nozzles, lances, and accessories available for specialized blasting in confined spaces, piping, and other irregular shapes. The SSPC is currently preparing a guide for the use of water blasting with and without abrasives.

High pressure water blasting without sand has not shown the capability of removing tigh rust, intact mill scale frcm steel except at exceedingly slow rates, or at Ultra high pressures (>30,000 psi) . In addition high pressure water cannot groduce profile (surface roughening) of the steel. In order to introduce additional erosive force into water blasting, abrasives must be incorporated into the water jet.

3.6 PRESSURIZED WATER ABRASIVE BLASTING

This category encompasses units with water 0p?essures from 2,000-15,000 psi. The FlOw rates are normslly 5-15 gallons of water per minute. It requires a different type of nozzle than used for straight high preessure water jetting. The nozzle orifice must be large enough (typically 3/8 in.) to prmit tie abrasives to wss through. Representative nozzles are shown in Figures 3-9 to 3-12.

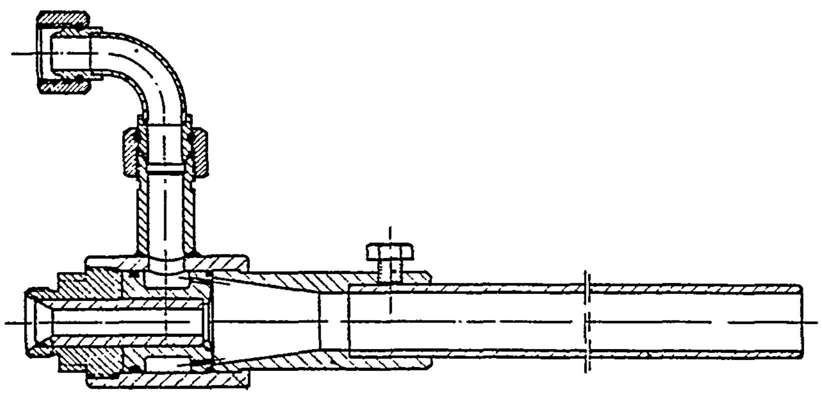


Figure 3-9 High Pressure Water Abrasive Nozzle (Courtesy of Hammel.mann)

When abrasive is added to the water stream, the relationships in Table VI, based on the density of pure water, are no longer valid. The abrasive stream normally decreases the velocity of the water jet and reduces the back thrust. This reduction is estimated at 15-30$ based on some data furnished by equipnent suppliers. However, at 10,000 psi, most of the water blasters are considered to have unacceptably high thrusts for continuous operation by one operator. These would require multiple operators to switch off every 60 minutes or less. The resulting efficiency would be greatly decreased. According to the NACE standard RP-01 -72, pressures above 5,000 psi constitute a hazard because they are difficult to handle and put undue stress and strain on the operator. A complete high pressure abrasive blasting unit is shown in Figure 3-13.

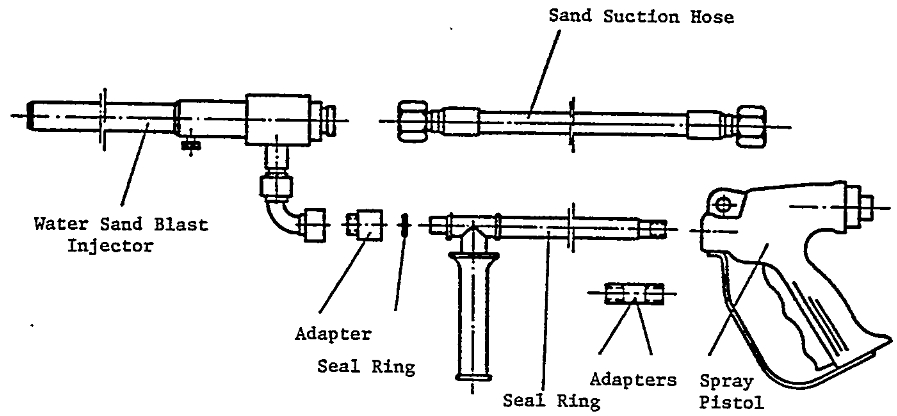


Figure 3-10 High Pressure Water Abrasive Gun and Nozzle (Courtesy of Hammelmann)

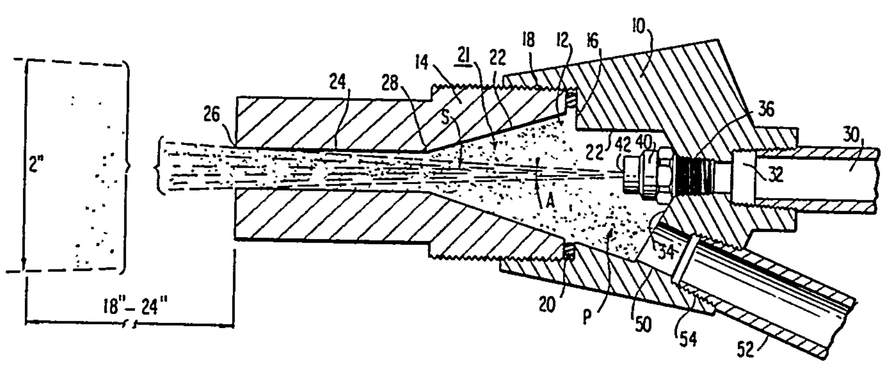
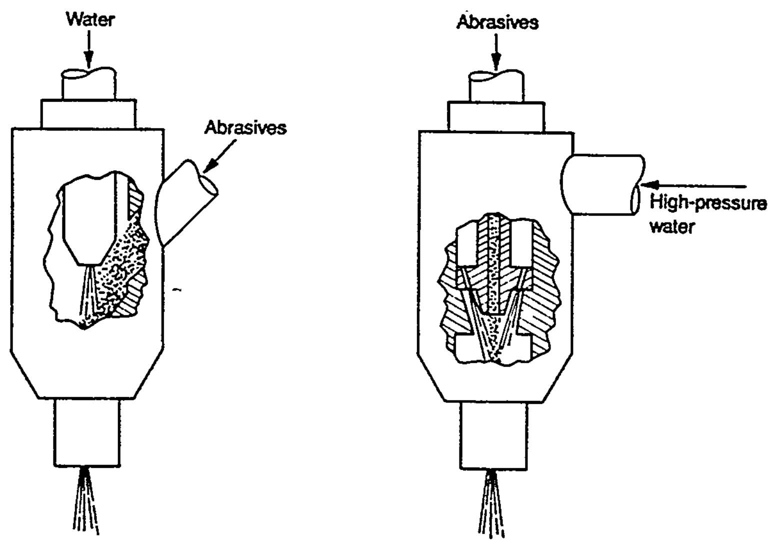


Figure 3-11 Low Pressure Water Abrasive Nozzle: Single Orifice (Courtesy of Hydrosander)

For this reason, we observed several units which operated at substantially lower pressures and thrust rates than those given above. Water blasters with pressures of 3,000-4,000 psi would be expected to provide much greater ease of handling and safety than the high pressure units. A few of these were simply high pressure units operated at reduced pressures. Others were designed for use at lower pressures. Low pressure water blasting without abrasive is used extensively in other cleaning operations which



(A) Single waterjet with side abrasive feed **(B)** Multiple waterjet with central abrasive feed

Figure 3-12 Comparison of Single- and Multi-Orifice Nozzle (Courtesy of ECEC Cleaning)

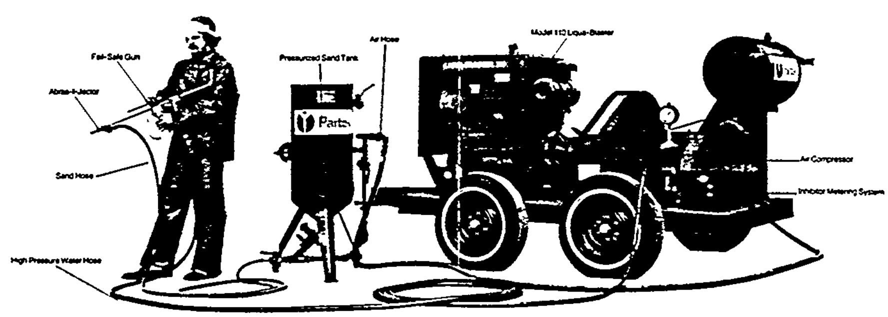


Figure 3-13 High Pressure Water Abrasive Blasting Unit (Courtesy of Butterworth)

do not require the erosive force necessary for surface preparation of steel.

3.7 WATER-ABRASIVE ("SLURRY") NOZZLES

There are several nozzle designs available which introduce the abrasive into the water stream. Most of these rely on suction by the water stream to pull the abrasives into the nozzle. some manufacture ers recommend use of a pressureized abrasive supply. This is claimed to provide a more regular flow of abrasives into the water stream. It is also claimed that suction delivery results in greater wearing out of the internal parts because the full internal diameter is needed to get enough abrasive sucked through the nozzle. The pressure type addition reduces the amount of wear and the abrasive co nsumption. One unit uses a 5 hp 30 cpm 50 psi air compressor to provide air for a 300 lb capacity pressurized sand hopper. The compressor is connected to the Pump crankshaft. Other users, however, prefer a venturi suction nozzle.

Figures 3-10 and 3-11 show some designs used for introducing abrasives into the water stream. Water enters the nozzle at a 15-30 degree angle through tiny ocrifice inserts (Figure 3-1 0). An alternate design which has recently been patented is shown in Figure 3-11. It is claimed that this design makes it possible for the water to maintain the maximum velocity, minimize the loss of energy, and deliver more abrasive at higher impact. Other single orifice nozzles also have the water entering the nozzle at O degrees with the abrasive entering at a low angle (from 15-30 degrees). Figure 3-12 compares the geanetry of single and multi-orifice nozzles. A discussion of the relative merits of these nozzles is beyond the scope of this investigation. However, it was noted that there were considerable differences in the cleaning rates of several of the units tested, which could be attributable to the design variables.

Another important parameter in water blasting, both with and without abrasive, is the standoff distance. At a small standoff (2 to 3 inches), the force of the jet on the surface is greatest, resulting in the highest degree of erosion. However this also results in a smaller gath width, and a lower overall c1eaning rate. It is important to adjust the standoff distance according to the type of surface layers keing removed and the operating characteristics of the particular unit. Similarly, fan jets (which distribute the water in a 15-60 degree cone or arc) provide a greater path width, but at a reduced intensity of erosion.

3.8 INHIBITORS

Because of the tendency of wet steed to corrode rapidly (flash rust), inhibiting chemicals are often applied to the freshly blasted steel surface. The inhibitors are usually water soluble chemicals which prevent corrosion by passivating the steal. surface (slow down corrosion by incresz ing the polarization). typical inhibitors used in water or wet blasting are as follows:

- 0 Sodiun nitrite
- o Anmonium *osphate

o Polyphosphate
o Thisodium Phosphate
o Sodiun dichromate

Many commercial inhibitors use a combination of nitrite and phoshate. The use of chromate type inhibitors has greatly diminished because of the safety, health, and envirmnental concerns. ,

Inhibitors can be added in several manners. The most common method is to add the inhibitor to the water during the blasting operation. The inhibitor may be added in tulk to the water tank, truck, or drum a can be metered in at a Prescribed rate. The latter is Weferred to attain more uniform concentration of the inhibitor in water. However, in some of the high volume water sand blasters, this technique would consume large amounts of inhibitor, An alternative technique is to apply an inhibitive solution as an after-rinse following the blast c1eaning. Tbis technique requires a different type of control and may aI1ow the surface to flash rust bfore the final inhibitive rinse is completed. Another variation is to apply the inhibitor by a separate application, such as roller, brush, or even a spray

Typical recommended concentrations for the nitrite and phos@ate inhibitors in water or wet blasting range from 100 to 3,000 parts per million (Pm) . There are few data relating the quantity of inhibitor n?eded per area to the time of protection afforded in environments of varying de gyees of severity. There are sl so few data comparing the merits of the different inhibitors. In =veral al' tie demonstrations, sn inhibitor p? evented the flash rusting which was observed to occur in the absence of the inhibitor.

Another important consideration of inhibitor use is the effect it has on the performance of the pint system. The inhibitors are water soluble species which tend to form mystalline materisls upon evaporation of the water. Ihus, osmotic blistering may result frcm tie soluble salt on theh surf ace. However, as noted above, these salts can interact with the steel to form a passive protection layer. There is as yet little substantiated data to show what, if sny, effect these inhibitors have on paint performance. Some preliminary experimental data from commercisa evaluations indicate that controled amounts of specific inhibitors have no effect after accelerated tests or cutdoor exposure tests of up to 5 years on n?w steel. There are reported instances of loss of paint adhesion within a few months due to ap@ication of excess or incompatible inhibitors. On the otherhand, failures have also occurral when paints (partiCculary high-solids chemi0cally curing paints) were applied over a thin layer of rust bl0IXU. Therefore when wet blasting, the decision of whether or not to use an inhibitor must consider the risk of failure attributed to both using and not using an inhibitor.

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SECTION 4

RESULTS OF DEMONSTRATIONS

The wet blast units demonstrated are listed in Table VII according to the categories discussed above.

TABLE VII

WET BLAST UNITS DEMONSTRATED

Air Abrasive Wet Blast

Clemtex WABB 60031
Service Painting Water-Sand Blaster
Clemco Wet Blast Injector System

Air-Water-Abrasive Slurry Blast

Willisms Air/Water/Sandsand
Hydrair

High Fressure Water Abrasive Blast (6,000-15,000 psi)

American Aero WBD-90
Aquadyne

Low Pressure Water Abrasive Blast (2,000-4,000 psi)

American Aero WBD-90
Hydro-Sander

Ultra High Pressure Water Blast (20,000-50,000 psi)

Butterworth Liqua-Blaster

4.1 JTR ABRASIVE E WET BLAST UNITS

The sir abrasive wet blast units overall gave the highest cleaning rate in comparison to dry blasting. For certain demonstrations on specific substrates, both the Clemtex and the Service Painting units gave rates higher than dry blasting. The water is added to the abrasive just before the nozzle for the Clemtex unit and just after the nozzle for the Service Painting unit. The operation is very similar to conventional dry blasting. The additional weight of the water hose made these units slightly more cumbersome than dry blasting. The spray-back of water and wet sand c1 inging to the surface made observation and control ‘of the cleaning more diffiCult. These units also showed a higher incidence of equipment breakdown than dry blasting units. The size, shape, and hardness of the abrasive can significantly affect the Pr oduction rates. The removal of heavy mastic epoxy coatings was much lower tian for rusted or mill scaled steel.

The Service Painting unit used a much seater water flow rate than the others (Figure 4-1), but also Produced higher cleaning rates. The additional water could present more of a drainage problem. The other two units had very low water consumption rates. The Clemco Injector system is furnished as an add-on to existing dry blasting equipment (Figure 4-2); the control unit is very compact and portable (see Figure 3-4). The Clantex unit, which was observed twice is a complete unit, including blast pots and control devices (see Figure 3-5).

Figure 4-1 Air Abrasive Wet Blast Unit (Courtesy of Service Painting Company)

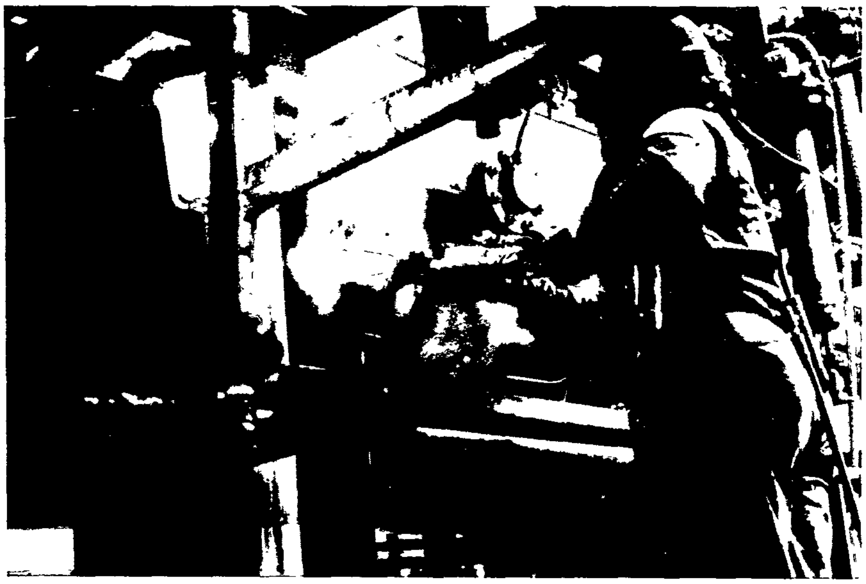

Figure 4-2 Air Abrasive Wet Blast Unit on field Trial: Clenco Wet Blast Injector (Courtesy of Clemco)

4.2 ATR-WATER-ABRASIVE SLURRY BLAST UNITS

The slurry blast systems were operated at lower nozzle pressures than the air/abrasive wet blast units, and consequently had s1ightly lower cleaning rates. These are designed for versatility in being able to feather-paint and spot clean as well as to completely remove paint and rust.

The Hydrair c1eaning rates were quite low compared to dry sand (see discussion in Section 5.1). The unit was very easy to maneuver on a scaffold in various configurations nad angles (see Figure 4-3). It was also quite easy to witch from wet abrasive blasting to water washing through the walki-talkie contact with the operator. The unit operator was able to monitor precisely the amount of water and inhibitor addition and to control these quantities. T he operator control of the slurry or sand the nozzle was very convenient for repositioning - oneself or adjusting the equipment. There was little bounce-back of abrasives or water on flat surfaces, but on edges or corners, a face-shield was required, and visibility was quite poor.

The air-water-sand system was somewhat more cumbersome than a conventional dry blast to cause of the water addition. Both of the observed sy e-temns had the capability for multiple operators with one control init.

Figure 4-3 Example of Air/Water/Sand Slurry Blast Unit on Highway Bridge: Hydrair System (Courtesy of Hydrair)

4.3 HIGH AND LOW PRESSURE WATER ABRASIVE BLAST UNITS

The high-pressure water abrasive blasters gave cleaning rates in the range of 30-50% that of dry blasting, in some trials rates as high as 80% or as low as 15% were obtained. Both units, when operated at 10,000 psi and 10 GPM gave very high operator thrust and were highly fatiguing on the operators. The large amount of water splashing made it difficult to see how well the area had been cleaned (see Figure 4-4). Because of this, there is a tendency to re-work certain areas or to miss areas, depending on the overlap. The sand consumption rates per hour are low. The units seem slightly more efficient at removing heavy rust buildup than tight mill scale or heavy paint layers. These units would be difficult and potentially dangerous to use on any type of platform or elevation. They are better suited to automated control than to hand operation.

The low-pressure water abrasive blasters were much more convenient and suitable as hand-held units than the high-pressure units. Unfortunately, we were not able to obtain direct comparisons of the cleaning rates versus dry blasting. The American Aero would be expected to give half the cleaning rates obtained at the high pressure, or about 20% that of dry blasting.

The Hydro-Sander unit was very effective at removing light rust and various types of paint including epoxy and inorganic zinc (see Figure 4-5). The manufacturer claims a unique, patented nozzle design which allows a greater path width and less energy loss during the passage through the nozzle. The unit was extremely easy to operate and was very portable. The

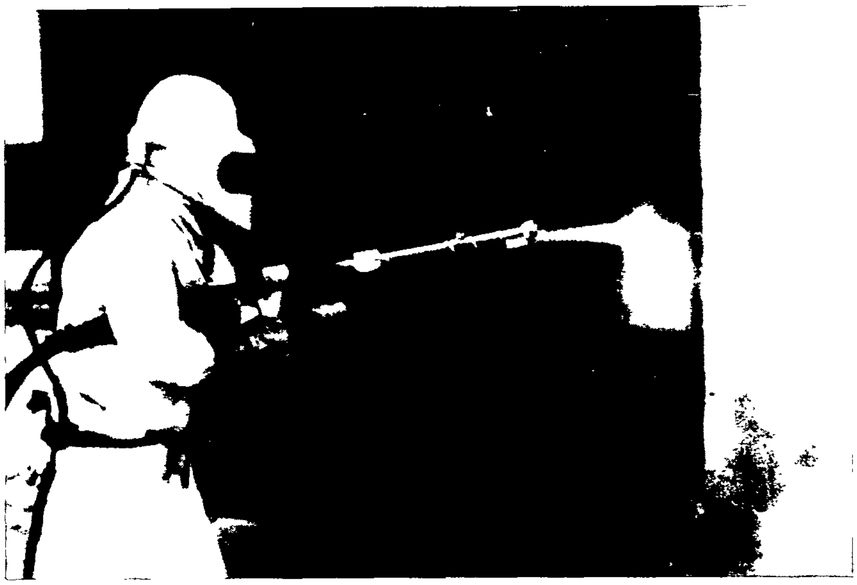

Figure 4-4 Example of High-Pressure Water/Sand Blaster: American Aero (Courtesy of Clemtex)

sand source was an open 5 gallon pail of sand. A dry blasting operation is shown for comparison of dust levels in Figure 4-6.

4.4 ULTRA-HIGH PRESSURE WATER BLAST

The Butterworth Liqua-Blaster operates at 20,000 psi and does not have any abrasive addition. Because of the high thrust, it was very difficult to control and proved very fatiguing, even to an experienced operator. The path width is small even with the 15-degree fan nozzle. As with the above high-pressure units with sand, the visibility was difficult, resulting in some inefficient cleaning. It removed topcoat and some primer relatively easily but was unable to remove mill scale (Figure 4-7).

Table VIII summarizes the operating parameters and cleaning rates obtained. Additional details on the observations, including specific substrate evaluations, and equipment parameters, are given in Appendix A.

Figure 4-5 Low-Pressure Water/Sand Blaster with Patented Nozzle Design (Courtesy of Hydrosander)

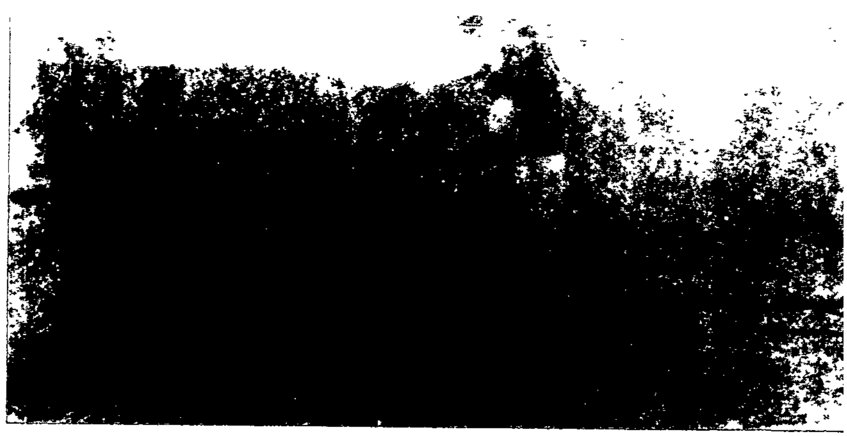

Figure 4-6 Dry Air Abrasive Blast System (Courtesy of Service Painting Company)

Figure 4-7 20,000 psi Water Blaster Without Sand (Courtesy of Butterworth)

TABLE VIII

SUMMARY OF FIELD DEMONSTRATIONS

A. AIR PRESSURED UNITS

UNIT	TYPE	NOZZLE PRESSURE (psi)	NOZZLE DIAMETER (INCHES)	WATER FLOW (GPM)	SAND CONSUMP. (LBS/SQ FT)	TOTAL AREA CLEANED (SQ FT)	CLEANING RATES VS. DRY BLAST (PERCENT)	COMMENTS
Clemtex WAB	Air Wet Blast	90-100	0.5	0.5	5	60	70-140	2 Separate Demos
Service Painting	Air Wet Blast	90-100	0.5	5-10	---	36	90-200+	Water Ring
Clemco Injector	Air Wet Blast	~100	0.375	1	---	~100	60-70	Retrofit to Dry Blast
Williams AWS	Slurry Blast	85	0.375	2	---	50	60-80	Micro Switch Control
Hydrair	Slurry Blast	90	0.5	0.5	---	10	20	Easy to Maneuver Walkie-Talkie Control

[a] Compared to 3/8 dry blast nozzle

B. WATER PRESSURED UNITS

UNIT	TYPE	NOZZLE DESIGN	WATER PRESSURE/FLOW (psi) (GPM)	THRUST COMPUTED (LBS)	SAND CONSUMP. (LBS/SQ FT)	TOTAL AREA CLEANED (SQ FT)	CLEANING RATE VS. DRY BLAST (PERCENT)	COMMENTS
Amer. Aero	Sand Suction	Multi-Orifice	10000 / 10	50[a]	11	16	30-40	Highly Fatiguing 2 Demonstrations
Aquadyne	Sand Suction	-	10000 / 8-10	40-50[a]	4-6	30	30-80	Highly Fatiguing
Amer. Aero	Low Pressure	Multi-Orifice	4000 /		-	7	-[b]	Easy to Control
Hydrosander	Low Pressure Sand Suction	Single Orifice 4° Cone	3000 /	11[a]	600 lbs/hr	4	-[b]	Easy to Control Efficient Cleaning
Butterworth Liqua-Blaster	Water Jet No Sand	Straight or Fan Jet	20000 / 9-10	65[a]	-	10	-[b]	Could Not Remove Tight Millscale Extremely Fatiguing

[a] Using formula for pure water, see Section 3 for effect of abrasive

[b] Suitable dry blast unit not available

SECTION 5

DISCUSSION OF FINDINGS

In selecting a surface preparation unit, or evaluating such units, there are several. factors that must be considered. These include the following: cleaning rates, cleaning effectiveness, equipment reliability, safety, portability and versatility of equipment, and cost. Each these factors is considered blow in view of the firsthand data collected in the demonstrations, secondhand data from other evaluators users, and manufacturers, and the technical and trade literature and discussions with various individuals.

5.1 CLEANING RATES

Overall, the cleaning rates with the air abrasive wet blasting were considerably higher than those using high pressure water. The former were approximately in the range of 80-90% the rates of dry blasting. The cleaning rates with high pressure water abrasive blasting were about 30-50% that of dry blasting, but were not as well documented as the air-driven systems.

Most of the rates quoted in the tables did not include times for set-up and c1ean-up. Cleaning rates also depend on the skill of the operatw. In most cases, the clean-up rate and expense are expected to be considerably higher for the wet cleaning methods than for dry blasting. Some of the field trials conducted by equipment manufacturers showed higher cleaning rates for some substrates. See Appendix C. These data, however, were not corroborated by the SSPC. The cleaning rates could be significantly improved by use of automated devices for supporting the nozzle thrust. An example of a recently developed unit with a four-nozzle array attached to an oscillating nozzle bar carrier is shown in figure 5-1. This particular unit uses water alone, but modifications to incorporate sand would be possible.

The high pressure water/sandblaster, and to a lesser degree, the air abrasive wet blasting reduce visibility. This often decreases cleaning rates because the operator cannot judge when he has sufficiently cl caned the surf ace and may repeat some areas and/or miss other areas. In addition, for the high pressure abrasive blaster, the stand-off distance (Figures 5-2 and 5-3) and the angle of blasting affect cleaning rates. They Will vary with the velocity of the jet (water pressure), nature of sub: strate and the type of cleaning (e.g. removing of topcoat or cleaning to bare metal) . The slurry blasting and the air abrasive wet blasting c1eaning rates, . as with any air blasting, depend on the air pressure. A

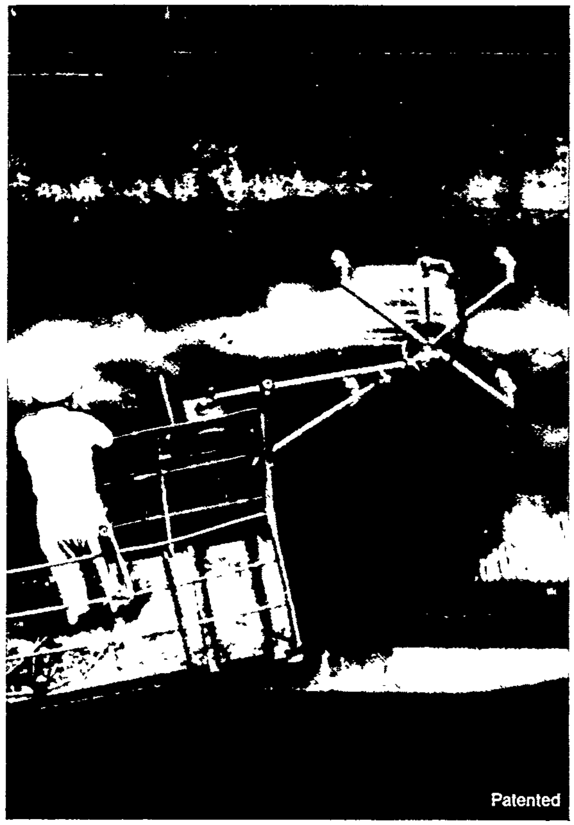

Figure 5-1 Automated 4-Nozzle Water Blast Cleaning Unit (Courtesy of WOMA Corporation)

few of the slurry blast systems recommended lower pressure (70-80 Dsi) psi ease of handling. This makes it easier for the operator to control the units and to remove the topmats or spot blast without damaging sound underlying paint.

The high pressure abrasive blasting units generally gave cleaning rates 1/3 to 1/2 that of dry blasting. The cleaning rate is increased at higher pressures or flow rates, but these also increase the thrust and the difficulty of controlling.

Several of the lower pressure water abrasive blasting units gave cleaning rates that would be acceptable for many small to medium sized j obshs. This would be particularly true for cleaning intricate structures or for maintenance crews. The rates for these units are estimated at 15-25% that of dry blasting.

Figure 5-2 Removing Faint with Pressurized Water/Sand Blasting (Courtesy of Weatherforci)

Figure 5-3 Cleaning Rusted and Pitted Steel with Pressurized Water/Sand Blasting (Courtesy of Weatherford)

5.2 CLEANING EFFECTIVENESS

The major factors in determining effectiveness are:

- o Visual Cleanliness (rmoval of rust, mill scale, paint and dirt)
- o Chemical Cleanliness (removal of oil film, soluble salts such es chlorides and sulfate)
- o Surface Profile

Each of the types of wet abrasive blast units was capble of producing near- white metal. However, in most of the observed demonstrations, the operator did not achieve a surface of 100% SP-10. Portions of the surface were rated at SSPG-SP 6 or SSP&SP 7. This is attributed primarily to the lack of visibility (see Figure 5-4). A uniform SSPc-SP 10 surface was hard to produce with high Pressure water blasting because of the small area cleaned by each pass.

Figure 5-4 Poorly Cleaned Areas in Corners. Also Shows Cleanup Problem. (Courtesy of Williams Contracting)

Thus the porest cleaning was obtained for corners and to bottom where visibility was poorest (Figure 5-5). Overall the air/water/abrasive slurry blasters gave the test visibility and slightly more thorough cleaning than air abrasive wet blasting. For the high pressure water-abrasive blasters, the operator fatigue and poor visibility resulted in less well-cleaned surface? (Figure 5-6). High pressure water at 7000 psi without abrasive was unable to remove tight epoxy paint (Figure 5-7) .

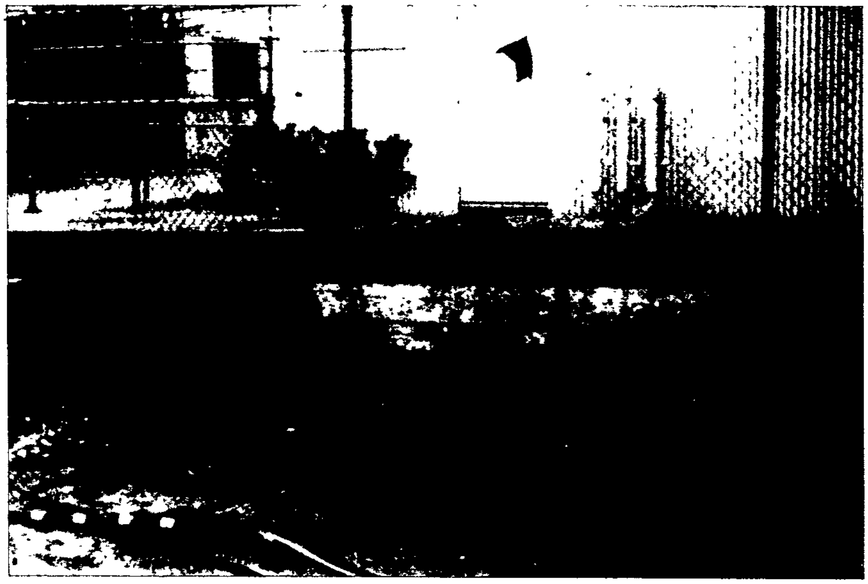

Figure 5-5 Surface Produced by Dry Blssting (left) , Air Abrasive Wet Blasting (center) , and Hgh pressure Water Blasting (right). (Courtesy of Cleantex)

A number of technical articles and trade literature have asserted that wet blasting methods are superior to dry blasting in removing soluble salts from steel. These salts are often considered to contribute to early rusting of previously exposed structures. However, determining the presesence, levels, or effects of the soluble salts was beyond the scope of the present investigation. Some of the more relevant discussions are given in the reference section. The effect of inhibitors in controlling flash rusting is illustrated in Figure 5-8.

For most of the emonstr ations, surface profile of the blasted steel was measured using replica tape and comparator. The data did not show any - difference in in profile obtained with wet blasting versus dry blasting. The most important factor for profile is the abrasive and the nozzle pressure. For high pressure abrasive blasting, the profile is primarily depndent on the type of abrasive used; at 10,000 psi the surface profiles were comparable to those for air abrasive wet blasting. Pressurized water without sand, even at ultrahigh pressures, will not produce a surface pofile.

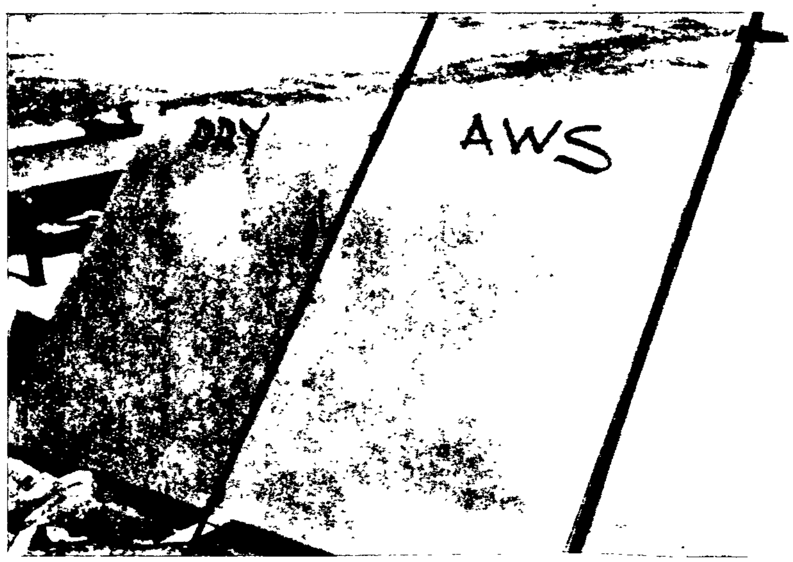

Figure 5-6 Dry Blast Without Inhibitor (left), Wet Blast With Inhibitor (center), and Wet Blast Without Inhibitor (right). (Courtesy of Williams Contracting)

5.3 RELIABILITY

Dry air abrasive blasting has been in use for many years with standardized and proven equipment. To a lesser degree, this is also true of high pressure water jetting equipment. Air abrasive wet blasting and high pres-sure water abrasive blasting are relatively new techniques with many recent innovations and modifications in equipment. In addition, the mechanics are more complex because of the need for special nozzles, mixing chembers, and the effects of a slurry on the internals of the system.

Thus, it is expected that these units will experience a greater degree of equipment malfunction and breakdown. Several instances of -equipnent mal function were observed in the demonstration. These included problems with the dead-man control switch, blockage of blasting nozzles, and loss of pump pressure.

The service and responsiveness of manufacturers depends on many factors. Among the critical ones are the availability of spare p?mts, knowledgeability of sales and service engineers, and experience of the manufacturer and distributor. Some of the units used commercially available components, whereas others had specially designed and manfactact ur ed components. The former would be expected to be more readily available, and to have had more of the design problems worked out.

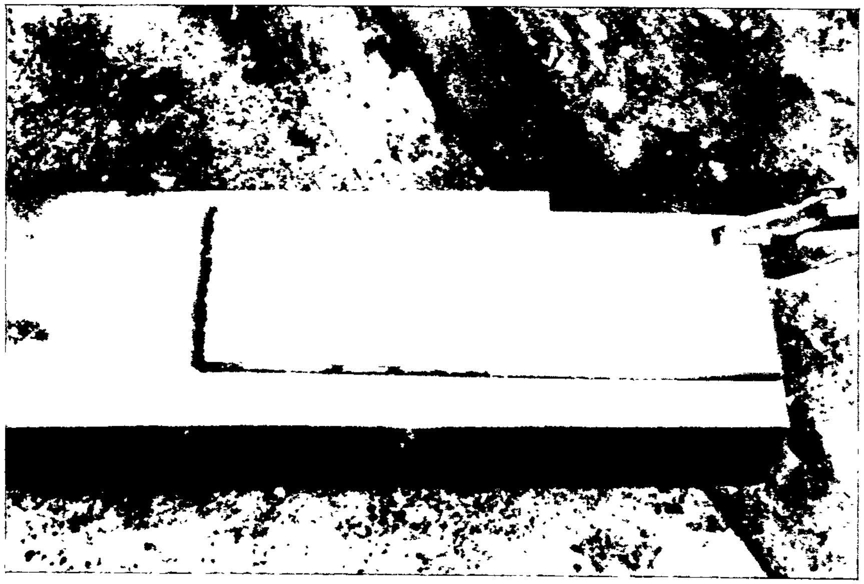

Figure 5-7 Effectiveness of Cleaning with 7,000 psi Water Jet Without Sand (Courtesy of Weatherford)

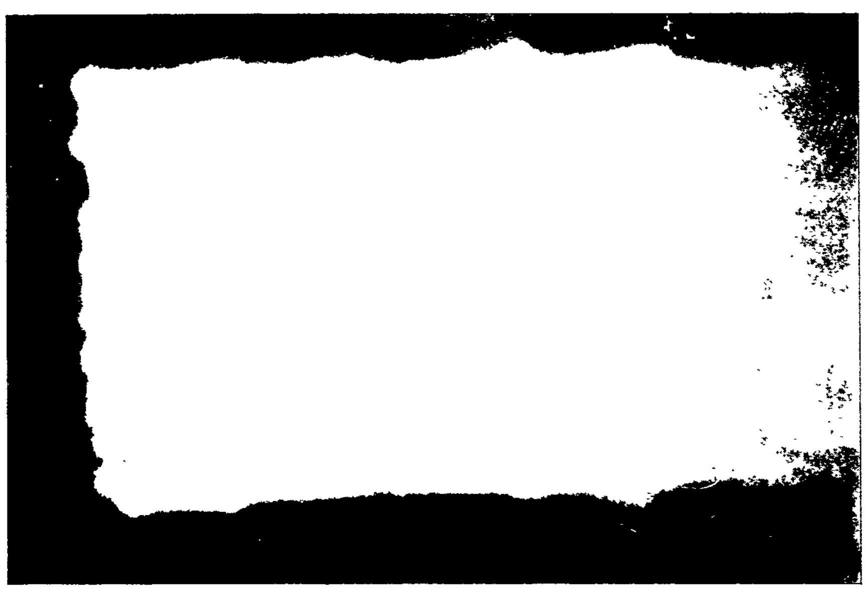

Figure 5-8 Illustration of Poorly Cleaned Areas (Courtesy of Clemtex)

Because of the possible need to make on-the+spot repairs, it is advantageous to have components that are. relatively easy to assemble and replace. There is considerable discussion in the Product literature regarding the rd. ative merits of the pumps used for the high pressure water units. The need for a high-roll. reliability, low-minte nance pump is obvious.

The fluid pressure unit (e.g. sir compressor or pump) is perhaps the most critical component of the system. It is important to provide a pump or compressor of sufficient size and power for the job.

The investigation did not deal with the serviceability of the equipment. The techniques and equipment of air abrasive blasting (without water) are well documented in NACE, SSPC, and other sources. However, we did not find comparable technical information regarding the operation of high pressure water jetting units. Most of the information derived came from trade literature and discussions with knowledgeable persons in the equipment or contracting business. The U.S. Water Jetting Technology Association may be able to provide more information on this subject.

5.4 SAFETY

The use of high pressure water jetting, wet blasting, or air abrasive blasting equipment can be dangerous and requires training of the operating personnel and observation of safe operating practices.

General safety requirements include dead-man controls on pressurized units, operating within the recommended limits of the air compressor or pump, properly reinforced hose, proper scaffolding, removing unnecessary clutter or obstructions from work area, and cordoning off work areas.

5.4.1 High Pressure Water Jettinj? Safetv

There are several organizations which have prepared or are in the process of preparing deteiled safety guidelines for this type of equipment. Some of the most important safety factors are as follows:

- Ear Protection: typical noise levels are in the range of 90 decibels
- Team versus Single Operation (one organization recommends that a single operator be allowed to operate units only up to 2,000 psi; above that at least 2 persons are required)
- Guard Against fatigue: a prescribed time should be set for the continuous blasting by an operator
- Eye and Head Protection: at the minimum goggles and face shield are required. Full over-the-head hoods may be required in some uses.

- o Safe Fluid Shutoff: this should be a dump device which cuts off the pressure when the handle is released.
- o Guns Preferred to Lances: this is the recommendation of the British Association of High pressure Water Jetting Contractors.
- o Gradual Increase of Thrust: the operators should experience the reaction force (thrust) progressively rather than al1 at once to start the operation.
- o Steel Toed Shoes
- o Cumulative Effect of Pressure (operator may receive a severe jolt when the dump valve is operated. This can be minimized by reducing hose length or by incorporatng damping devices into the system.)

Additional details are available from references and from a forthcoming guide by the U.S. Water Jetting Technology Association.

We are aware of several instances where operators have lost a toe or an eye from high pressure water jetting. It should be emphasized that the high pressure flow rate units have a high operator thrust (40-50 lbs) and are very difficult to control safely on a platform or other area of precarious footing.

5.4.2 Air Abrasive Water Blasting

One of the most important safety features is the cut off valve for the air blast nozzle (Figure 5-9). In one of the demonstrations, we observed operators using defective nozzles. The safety lock, designed to shut off the flow when the grip is released, failed to so, or did so sporadically. We were informed by one manufacturer that the wet sand can block the spring action and that it is necessary to keep this machine free of debris. This type of incident, rare though it may be, highlights the need for users to conduct priodic maintenance on the equipment as recommended by the manufacturer. A general safety check should be made each day before the equipment is operated and defective portions fixed or replaced.

Although air abrasive wet blasting does cut down considerably on the visible dust, small Particles may be trapped in water particles and deposited in the lungs. The use of NIOSH approved air-fed respirators is strongly recommended. Thus, whereas these units apparently are successful in controlling environmental problems, they are still considered a possible hszard for worker health. This is prticularly relevant in light of the numerous cl claims on silicosis currently existing against manufacturers of abrasive equipment.

There is little evidence that the use of wet abrasive blasting in any way reduces the risk of sparking from the blast nozzle. Thus, their use in

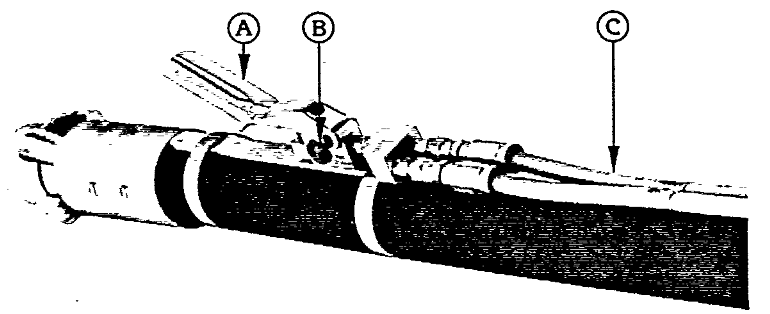

Figure 5-9 Safety Lock on Abrasive Blasting Nozzle (Courtesy of Clemco)

tanks or vessels containing volatile materials must still be closely controlled and monitored.

5.5 PORTABILITY AND VERSATILITY

The present investigation was directed at field cleaning of steel. The ease with which various units can be transported, as sembled, and transferred is an important factor in their suitability for certain jobs.

Naturally, smaller cleaning units will require smaller compressors, pumps, and sand pots and therefore be more easily transported. Weighed against this is the lower productivity rate and efficiency of the low-powered units.

One of the major considerations is the source or supply of water and/or abrasives. The high-production rate water blasting unit requires 10 gallons per minute, thus for 6 hours of blasting, it will consume 3600 gallons of water. IF a water source is not readily available (e.g. on a highway bridge) water must be transported to the site by tank trucks. This would be a disadvantage for this type of unit. On the other hand, water is usually readily available at Plant or shipyard facilities.

Another important consideration is the relative amount of sand required. The data from the demonstrations show a considerable amount of variability in the amounts of and required by different units. the slurry blast units and a few of the pressurized water blast units use relatively low quantities of sand as compared to air abrasive wet blasting. However, as noted, this depends considerably on the specific unit and abrasive selected.

For a large production job, the volume of sand required may be the most serious logistics problen. There would be little advantage in using a small compressor and sand pot. It is important to use a unit sized properly for the job. The air/water/abrasive slurry systems observed were designed for large production jobs; each had seversl. manifolds from one control unit. In these units the addition of water to the sand was controlled at one location. For units in which water is added at the nozzle, each nozzle would require a separate water hose, and possaibly a separate inhibitor metering system thus the slurry blast system might be more efficient for jobs in which several blasters can operate from a single control Unit. On the other hand, the smaller, retrofit abrasive wet blasters or self-contained units would be more appropriate where the total amount of steel in any one area is not large enough to warrant more than two blasting nozzles.

The high pressure water hoses have a relatively small Pessure loss. This enables the operator to reach several hundred feet without relocating the pump. For water jetting at elevated heights, supplental boosters are available to maintain the high pressure. In addition, pressurized sand hoppers can be used to force the sand through several hundred feet of hose.

Air blast hoses for wet or dry abrasive blasting are normelly limited to about 100-200 feet unless very large compressors are used. It is generally advisable to place the sand pot as close to the nozzle as possible.

5.6 COST

The evaluation of cost entails a number of factors, some of which are difficult to determine. These include labor and production rates, capital equipment costs, maintenance expenses, operating expenses, support crews, insurance, and materisls. The determination of cost must be done on an individual basis and related to the requirments of the job.

The purchase price for the units reviewed varies from a couple of thousand dollars to around $50,000. The least expensive units are the low pressure water abrasive blasters which utilize sand suction only. These are equipped with relatively low-power pumps and do not have the capability of exceeding 3,000-4,000 psi.

Also in the lower price range are the units for retrofitting existing dry abrasive blast units. For those who already own an abrasive blasting system, this can be an easy low-cost way of getting into wet blasting. The purchaser of such a unit must be aware that use of the add-on for wet blast will result in the following effects in comparison to dry blasting:

- Lower cleaning rates
- Higher clean-up costs
- Higher maintenance costs

The low pressure water abrasive blasters discussed earlier will result in considerably lower c1eaning rates, particularly on achieving near-white or commercial blast finishes.

The next higher price range includes the high pressure water abrasive blasting units, and the complete system air abrasive wet blast units. The cleaning rates of the air abrasive wet blasting are comparable to that of the retrofit abrasive blasting units. The owner is now also paying for a larger control unit and a sandblasting machine.

The major cost for the high pressure water abrasive blasting system is the pump. A higher volume pump can supply high pressure water to several water blasting arrays.

The top range of cost would be for the multi-modal air blasting systems. These were Primarily slurry blast systems. They consist of a central. control unit that has the capability of independently controlling the individual nozzles as well as the air/water/abrasives and inhibitor. Normslly, a single control unit operator can coordinate several blasters, thereby improving the efficiency for large production johs.

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SECTION 6

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APPENDIX A

NOTES AND DATA FROM FIELD DEMONSTRATIONS

A.1 COMMENTSTS ON DEMO NO. 1

A.1.l Butterworth Liaua-Blaster

This unit, at 20,000 psi, has a very large operator thrust and is difficult to control. Fifteen minutes was about the maximum that even a trained operator could handle the equipment. This unit has a snail Path width even with the use of the 15-degree fan. In addition, because of the large amount of water, it was difficult to see precisely what had been accomplished. Another fact or in obtaining optimum cleaning rate, the stand-off distance, was made more difficult by the visibility problem. This results in missed areas and relatively inefficient cleating. Consequently, it is usually necessary for the operator to try to rework certain areas to insure that they were cleaned. After the first pass there were a number of missed areas (i.e. paint remaining) which had to be cleaned in a second pass.

The initial pass removed essentially all the topcoat, also the primer, but a large portion of the mill scale remained on the steel. A third pass was required to completely remove the mill scale to give an SSPC-SP 10. The cleaning of inorganic zinc, which had been applied over a blast cleaned surface, was slightly more efficient (Table A-1).

A.2 COMMENTS ON DEMO NO.2

A.2. I American Aero Water Blast Unit with Sand Suction

This unit was operated at 7,000 and 4,000 psi. At 7,000 psi the thrust was manageable, but with some difficulty. At 4,000 psi the unit was quite easy to handle. The visibility at this pressure was good. The cleaning was easy to monitor. The cleaning rate was more dependent on how fast the operator could move the unit along the steel and not as dependent on the stand-off distance. At 4,000 psi the cleaning was slow, however, and the operator had to work the area to remove the rust and the paint. Low pressure application could be handled efficiently for a couple of hours. Howwer, it was considerably slower than the 7,000 psi cleaning rate. The dry sandblast control was not a very good unit. The nozzle was only 1/4

TABLE A-1

REFINERY -- BATON ROUGE, LOUISIANA
(Demo No. 1)

Butterworth Liqua-Blaster

Water Pressure (psi)	20,000	20,000	20,000
Flow Rate (gpm)	9.5	9.5	9.5
Substrate	Tanks, Painted Mill scale	Tank, Painted Mill scale	Tank, Painted Mill scale
Final Condition	Tight Mill scale, Slight Paint	SSPC-SP 10	SSPC-SP 10
Area Cleaned (sq. ft.)	-10	-10	-7.5
The (min:sec)	6:45	16:15	9.0
Cleaning Rate (sq. ft. /hr.)	-90	-40	-50

inch diameter. Pressure at the nozzle was not measured, but it was suspected to be considerbly derably less than 100 psi.

A.2.2 American Aero Water Blaster Without Sand

The unit was operated up to 10,000 psi and could not remove the heavy rust from the rusted and pitted pipe. Without sand it was also very Slow at removing an epoxy topcoat. The effect of changing the type of nozzle from straight jet to fan jet had little effect on the cleaning rate. The stand-off distance, however, was an important factor.

For this demonstration sand was added by suction rather than power pressure feed. According to the manufacturer, the suction system results in sporadic and nor-uniform rate of sand delivery. It also results in greater wearing out of parts of the nozzle, because a full internal diameter is needed to get enough sand sucked through the nozzle. The rate of sand consumption is reduced to 500-600 lbs per hour with the pressure feed versus 900 lbs per hour with suction.

At 7,000 psi the thrust was extremely high end it was very difficult to lift the unit to & vertical or overhead members. The representative agreed that this system is not suitable for use on scaffolding or for hand held operation in tightly confined areas. It is peferable to use it on an automatic controlled rig.

Without inhibitor, the blast cleaned specimens began flash rusting within 15 to 30 minutes. It was a humid day with scattered showers. The inhibitor (Sharp Chemical Company Mibitor 104), a two-component product, was effective in controlling the flash rusting. (Table A-2).

NOTE: Because of the small areas cleaned, meaningful cleaning rates could not be estimated for the test plates cleaned.

A.3 COMMENTS ON DEMO NO.3

A.3.I Clemtex Wet Abrasive Blaster (WAB 60031)

This is the same unit which is described in Demo No. 4. There were some problems with the compressor in this demo. The inorganic zinc was able to be cleaned quite rapidly by this unit. Rusted and pitted steel plates took somewhat longer and the heavy layer of 5-6 coats of paint was longer by a factor of 2 or 3. For the heavy coating removal, a different type of sand (Specialty Blast Sand No. 2) was used instead of the Clemtex Sand No. 3 which had run out.

A.3.2 Service Painting Water/ Sand Slurry Blaster

This unit used a large volume of water, comparable to that used for high pessure water blasting. The cl caning efficiency was extremely high, consider ably greater than that for the Clemtex WAB unit and overall superior to the dry sandblasting. Because of the rapid cleating rate, this unit used less sand per square foot than the other air abrasive units. This unit may be slightly more cumbersome to handle because of the larger volume of water.

A.3.3 Aguadyne Water Blaster with Sand Suction

This unit had the highest thrust of the units demonstrated. It also exhibited the lowest cleaning rate by a factor of about two. However, it also showed the lowest rate of sand consumption per square foot of surface cleaning. Both the wet abrasive blasting units and the Aquadyne unit were effective in keeping down the dust in amparison to the dry sandblaster. The Aquadyne unit had relatively poor visibility because of large amounts of overspray. It would probably be easier to clean up because of the smaller volume of sand than the other wet blasting unit (Table A-3).

NOTES AND DATA FROM FIELD DEMONSTRATIONS

TABLE A-2

YARD FACILITY -- CLEVEL AND, CHIO
(Demo No. 2)

	American Aero water blast	American Aero + sand	American Aero + sand
Water pres. (psi)	7000	7000	4000
Flow Rate (gpm)	10	10	----
SUBSTRATE A	4-INCH DIAMETER PIPE. PITTED AND RUSTED		
Final Condition	Heavy rust not removed	SSPC-SP 6/SP7	SSPC-SP 6
Area Cl caned (Sq. ft.)	-------	1	1
Time (min:sec)	-------	0:40	1:50
Cleaning Rate (sq. ft. /hr.)	-------	90	35
SUBSTRATE B	2-FOOT DIAMETE R BARREL. LIGHT TO MODERATE RUST		
Final Condition	-----	SSPC-SP 6	SSPC-SP 6/SP 7
Area cleaned (Sq. ft.)	-----	6	6
Time (min:sec)	--------	1:30	2:00
Cleaning Rate (sq. ft. /hr.)	-------	240	180
SUBSTRATE C	EPOXY POLYAMIDE PLATE. 2 COATS (4" x 12")		
Time (min:sec)	1:15 (topcoat only)	0:14	0:20
SUBSTRATE D	INORGANIC ZINC-RICH PRIMER (4" x 12")		
Time (min:sec)	1:40 (0:75)[a]	0:08	0:18
SUBSTRATE E	HEAVILY RUSTED STEEL PLATE. GRADE D (6" x 6")		
Time (min:sec)	0:30 (loose rust only)	0:18	0:30

a - using fan jet instead of straight jet

TABLE A-3

YARD FACILITY -- BEAUMONT, TEXAS
(Demo No. 3)

	Clemtex (WAB 60031)	Water/Sand Slurry Blast	Aquadyne Sand Suction	Dry Sand
Air Pres. (Psi)	92	90-100	-----	100
Nozzle Dia. (inch)	1/2	1/2	-----	3/8
Water Pres. (psi)	— ---	30-40	10-11,000	-----
Flew Rate (gpm)	1/2	5-10	-----	-----
SUBSTRATE A	STEEL PLATES, SLIGHTLY RUSTING, INORGANIC ZINC			
Final Condition	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10
Area cleaned (Sq. ft.)	12	12	12	12
Time (min:sec)	2:50	2:10	7:00	2:00
Cleaning Rate (sq. ft. /hr.)	2 5 0[a]	330[b]	100[b]	360[b]
Sand Cons. Rate (lbs./sq. ft.)	15-20	6-8[b]	5-7[b]	-----
SUB STRATE B	RUSTED AND PITTED STEEL ELATES			
Final Condition	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10
Area cleaned (Sq. ft.)	12	12	12	12
Time (min:sec)	4:35	2:15	7:00	6:10
Cleaning Rate (sq. ft. /hr.)	160[a]	320[b]	100[b]	120[b]
Sand Cons. Rate (lbs./sq. ft.)	20-30[a]	6-8[b]	3-5[b]	-----
SUB STRATE C	STEEL PLATE, PAINTED (25 MILS.5-6 COATS. EPOXY/ALKYD)			
Final Condition	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10
Area Cl caned (Sq. ft.)	6	12	6	6
Time (min:sec)	5:05	6:25	13:15	5:20[b]
Cleaning Rate (sq. ft. /hr.)	70[b]	110[b]	30[b]	70[b]
Sand Cons. Rate (lbs./sq. ft.)	70-90[b]	30-35[b]	17-23[b]	40-60[b]

a - Clentex Sand No.3 b - Specialty Blast Sand No. 3

A.3.4 Dry Blast System

Because of the limited quantity of the Clemtex Sand No. 3, the Service Painting Company unit and the Aquadyne unit used the Specialty Blast Sand No. 3. In order to provide more direct comparison the substrate was dry blasted with both sands. The Clemtex sand showed significantly better cleaning rates and lower sand consumption than the Specialty sand.

A.4 COMMENTS ON DEMO NO. 4

A.4.1 Clemtex Water Abrasive Blaster

This unit was more difficult to control than the dry sand blast. The hose and nozzle felt heavier and were more difficult to whip around and move to a different location. In addition, the degree of surface cl caning was not as good as that for the dry sandblast. It was more difficult for the operator to determine when he had completely removed the rust and paint. Without inhibitor, at moderate humidity, the surface did not flash rust for about one hour. There was a slight delay of a couple of seconds between the closure of the operating latch and the actual stoppage of abrasive flow. The operator must be aware of this in order to use the equipment safely. There were some other problems with the sand flew. Several times the unit lost pressure. Because of the splashing back of the water, the visibility was less than for the dry blast, but still better than the high pressure water blast.

A.4.2 High Pressure Water Blaster with Sand Injection

This unit was both difficult to control and slower at cleaning than the water abrasive blaster. In fact, it was particularly difficult to control the gun in an Ovehead or even horizontal position. In addition, the visibility was poor because of the larger volume of water that was splashing off the work surf ace. It was difficult to see the area being cl caned to obtain the proper stand-off distance. The experienced operator, howwer, didn't seem to have this problem, but the surface was not cleaned as uniformly as with the dry blast because of the difficulty in determining which areas had been cleaned. There is no comparison in cleaning rates between this particular high pressure water blaster with sand and the Clemtex WAB unit or dry blasting (Table A-4).

TABLE A-4

YARD FACILITY -- HOUSTON, TEXAS
(Demo No. 4)

	Clemtex Abrasive Blaster (WAB 60031)	American Aero WBD 90 (Sand Injection)	Dry Sand Blast (Clemco SCWB 2452)
Air Pres. (psi)	100	----	100
Nozzle Dia. (inch)	1/2	_3/8	3/8
Water Pres. (psi)	-----	10,000	-----
Flew Rate (gpm)	1-1/2	10	-----
SUBSTRATE A	STEEL HOPPER , RUST GRADE A		
Final Condition	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10
Area Cleaned (Sq. ft.)	19	9	23
Time (min:sec)	4:05	7:20	5:25
Cleaning Rate (sq. ft./hr.)	279	74	255
Sand Cons. Rate (lbs./sq. ft.)	5.3	11.1	4.3
SUBSTRATE B	STEEL FLATES, RUST GRADE C		
Final Condition	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10
Area Cl caned (Sq. ft.)	4	4	4
Time (min:sec)	1:05	4:15	1:20
Cleaning Rate (sq. ft./hr.)	220[a]	56[a]	180[a]
SUBSTRATE C	STEEL REAM HEAVILY RUSTED, RUST GRADE C		
Final Condition	SSPC-SP 6	SSFC-SP 6	SSPC-SP 6
Area Cl caned (lin. ft.)	3	3	3
Time (min:sec)	0:50	2:30	0:55
Cleaning Rate (lin. ft./hr.)	275	72	195

a - Black Beauty used instead of sand

A.5 COMMENTS ON DEMO NO. 5

A.5.1 Clemco Wet Blast Injector System

This unit can operate sand and air only, water end sand only or various combinations. There is no visible difference in the thrust with water on or off while abrasive blesting. The dry sand nozzle cleans a analler path but cleans slightly more efficiently than with water. It is also easier to determine what portion has been cleaned. However, this unit has relatively good vision for a wet blasting system because of the low water volume. It is quite easy for the operator to switch from water and sand to plain water for washing off. It is also possible to turn off the and but retain the air.

There was an apparent safety problem with the operation of the deadman control switch. The valve which actuates the air sand blest is supposed to automatically open when the handle is released. This spring was not working properly and the operator had to manually open the valve to shut off the air pressure. In several instances, the valve closed by itself and the abrasive blast started UP. This could prove very dangerous. In one instance when the nozzle was lying on the ground and moved slightly, it started blasting and gouged a large hole in the ground where the nozzle was lying. Another time the nozzle started blasting after it had been placed over support racks and moved slightly. There may have been something clogging the valve, but the plant personnel were unable to correct it.

Although Clemco has developed an accessory which allows automatic addition of inhibitor, it was not available at this demo. There was no inhibitor used and the surface began rusting almost immediately (within 30 minutes). In addition it was rainy during much of the blasting operations and by the end of the day the surface was quite rusty and brown in appeaante. However, it was possible to remove this layer of rust with water pressure alone, without sand. me sand knob was turned off, and the water used with the 90 psi air which is normally used to propel the abrasive.

A sludge formed on the surfaces adjacent to the areas being blasted. The formation of sludge may have been increased because of the low volume of water. This sludge could present a clean-up problem, although it could be washed off with the water unit.

The tank used for the demo had been painted, but was very badly deteriorated. Most of the Paint was loose, peeling or gone. There was extensive rusting in many areas and some deep pitting. The Clemco unit had no trouble in removing both paint and rust from the steel..

The rate of cleaning was reduced by the lack of proper scaffolding. The operators used ladders which were moved frequently, and which did not provide optimum stand-off distances or blasting angles.

The unit was easy to control. There is little fatigue after using this for 10 or 15 minutes. The visibility is adequate, if the shield is periodically replaced (Table A-5).

TABLE A-5

CHEMICAL PLANT -- PENSACOLA, FLORIDA
(Demo No. 5)[a]

	Clemco Wetblast Injector System	Dry Blast
Air Pres. (psi)	100	go-loo
Nozzle Dia (inch)	3/8	3/8
Water Pres. (psi)	600	-----
Flow Rate (gpm)	1	— ---
SUBSTRATE	HEAVILY RUSTED HOT WATER TANK - SOME PITTING	
Final Condition	SSPC-SP 6	SSPC-SP 6
Area Cleaned (Sq. ft.)	l00-150[b]	5-6
Time (hr:min)	1:30-2: 00[b]	~0:03
Cleaning Rate (sq. ft./hr.)	60-90[b]	100-120

a - Starblast abrasive used
b - Unit shut off frequently to reposition ladder or change operator position

A.6 COMMENTS ON DEMO NO. 6

A.6.1 Hydrosander

Hydrosander is a low-pressure water blaster with sand injection. The unit observed was a 3,000 psi pressure unit with a flow rate of 4 gallons per minute. Because of the low pressure the thrust on this unit was quite low. It was very" easy to handle and maneuver around edges and would present little Problem with operator fatigue. Thrust is estimated at 12 lbs. Visibility was very good.

This unit was very effective in removing weathered paint from a steel barrel. It was also evaluated on organic zinc, alkyd, and epoxy paints. For the alkyd and zinc paints, the Hydrosander cleared a path about 2 inches wide, with one pass about 10 or 12 feet per minute. For the epoxy it required 2 passes to clear a path 2 inches wide down to bare metal (SSPC-SP 10) (Table A-6).

TABLE A-6

YARD FACILITY -- COLUMBIA. SOUTH CAROLINA
(Demo No. 6)

HYDROSANDER
(Water Blasting with Sand Suction)

Substrate	Painted, Rusted Steel	Alkyd & Inorganic Zinc	Epoxy Polyamide
Water Pres. (psi)	3000	3000	3000
Flow Rate (gpm)	4	4	4
Final Condition	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10
Area Cleaned (irregular)	-2-4 Sq. ft.	2 inch path	2 inch path
Time	-1-2 min.	1 pass	2 passes
Cleaning Rate (sq. ft./hr.)	-120	-----	----
Sand Cons. Rate (lbs. /hr.)	-600	-600	-600

A.7 COMMENTS ON DEMO NO. 7

A.7.1 Williams Contracting Air/Water/Sand Unit

The Air/Water/Sand unit developed by Williams Contracting had three manifolds from one control unit. It has the capability of automatically monitoring inhibitor. The blaster can actuate or cut off the sand instantaneously with a microswitch, therefore an additional. operator is not required at the sand pot. The water is shut off by unplugging the AWS unit, although this could not be automated. The air, water and sand can be independently controlled.

Some of the testing was done on confined areas of beams and channels. For these, it was obvious that the amuoun of splash-back from the air/water/sand unit caused severe visibility problems. This also caused fairly rapid wear of the face shield. It was very difficult to completely clean the rust from the corners. This was not true with the dry blast for which the rebound was much less of a problem. Thus, in cleaning these types of members, it is often necessary to re-do any missed areas after the initial cleaning. The SAnd and sludge that remains on the surface after blasting makes visibility difficult.

The air/water/sand unit was easy to maneuver and operate, however, the hose is fairly heavy when it has to be moved from one location to another or supported on a scaffold. There was very little fatigue and a reasonably robust operator cnuld use this unit comfortably for hours. There was a delay of about one second from actuating the switch until the sand shut off. It is quite easy to shut off the sand for washing down with water. When this is done, the amount of water volume is increased. There were also some delays in the wet blasting due to some condensation in the sand line (Table A-7).

A.8 COMMENTS ON DEMO NO. 8

A.8.1 Hydrair SyStem

The Hydrair system uses a combination of air, water, and sand which are also independently controlled. The primary thrust is provided with air abrasive blasting asting with the water used to control the dust. The water is added just after the sand leaves the sand pot. The control unit monitors the water flew and meters the desired amount of inhibitor into the water stream. This can be varied by the operator as required. The operator communicates with the control by a wslki-talkie. Thus this unit requires at least two men to operate.

The condition of the bridge beam used for this demo was painted mill scale which was badly deteriorating. The paint could easily be removed with a knife, but the mill scale underneath was tight.

The unit was extremely easy to operate. The SSPC operator felt very comfortable using it on a scaffold. One cnuld bend over and feel that he had complete control of the unit. The sand consumption rate was lower than that of dry blasting, although this demo not give precise data.

When blasting the flanges, edges, and corners, there was considerable rebound from the structure. As much as 30 to 40 feet away, observers could still feel the sand spray.

This unit has a special feature, a second moisture separator, which is apparently advisable in the Gulf Climate because of the humidity (Table A-8).

The Hydrair system cleaning rate ws only about 20% that of dry sand or coal slag. Some possible factors which contributed to this discrepancy are: dry blasting by experienced bridge blaster; possible variability in surface conditions or different sides of bridge; and greater ease of maneuvering dry blast equipment. The Hydrair system was effective at removing the paint and mill seale, but was not operated as efficiently as the dry blast units.

TABLE A.7

YARD FACILITY -- ATLANTA, GEORGIA
(Demo No. 7)

	Williams Air/Water/Sand	Dry Sand
Air Pres. (psi)	85	78
Nozzle Dia. (inch)	3/8	3/8
Water Pres. (psi)	500	----
Flew Rate (gpm)	2	----
SUBSTRATE A	STEEL PLAT, RUST GRADE C	
Final Condition	SSPC-SP 10 (75%) SSPC-SP 6 (25%)	SSPC-SP 10
Area Cleaned (Sq. ft.)	16	16
Time (min:sec)	4:20[a]	3: 20[b]
Cleaning Rate (sq. ft./hr.)	200	290
SUBSTRATE B	STEEL PLATES, RUST GRADE B, RUSTING MILL SCALE	
Final Condition	SSPC-SP 5	SSPC-SP 5
Area Cl caned (Sq. ft.)	16	16
Time (min:sec)	7:l0[a]	5:55[b]
Cleaning Rate (sq. ft./hr.)	130	160
SUBSTRATE C	ANGLES AND EDGES OF BEAM	
Final Condition	SSPC-SP 6 (90%) SSPC-SP 7 (10%)	SSPC-SP 6
Time (min:sec)	7:43[a]	6 :04[b]
SUBSTRATE D	CHANNEL -- 8" DEPTH X 2-1/2" FLANGE	
Final Condition	SSPC-SP 10	SSPC-SP 10
Area Cleaned (Sq. ft.)	-10	-10
Time (min:sec)	6:04[a]	3: 27[b]
Cleaning Rate (sq. ft./hr.)	100	170

a - includes time for wash-down   b - includes time for blow-down

TABLE A-8

HIGHWAY BRIDGE -- NEW ORLEANS, LOUISIANA
(Demo No. 8)

	Hydrair[a] Sand/Water	Dry blast Coal slag	Dry Blast Dry Sand
Air Pres. (psi)	90	45	45
Nozzle Dia. (inch)	1/2	1/2	1/2
Water Pres. (psi)	-----	-------	-- --
Flow Rate (gpm)	0.5	------	----
SUBSTRATE	BRIDGE BEAM (WEB. FLANGE). RUST, PAINT, MILL SCALE		
Final Condition	SSPC-SP 6	SSPC-SP 6	SSPC-SP 6
Area Cleaned (Sq. ft.)	10	60	105
Time (min:sec)	4:45	6:36	10:06
Cleaning Rate (sq. ft./hr.)	130	540	620
Sand Cons. Rate (lbs./sq.ft.)	-3	1.7	1.9

a - Abrasive Blasting with Water

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APPENDIX B

WATER AND WET ABRASIVE BLASTING EQUIPMENT AND SERVICES

AAM-RO Corporation Abrading Machinery & Supply Div. 2340 West Wabansia Avenue Chicago, IL 60647 312-276-6535	Water blasting equipment Wet abrasive blasting equipment
A-Bec Industries 1864 Vanderhorn Drive Memphis, TN 38134 901-372-3302	Water blasting equipment
Ace Enterprises, Inc. 820 NW 144th Street Miami, FL 33168 305-685-3848	Water blasting equipment
Acme Cleaning Equiment, Inc. P.O. Box 102 Seabrook, TX 77586 713-474-2876	Water blasting equipment Wet abrasive blasting equipment
A1kota Manufacturing, Inc. P.O. BOX 368 Alcester, SD 57001 605-924-2222	Water blasting equipment
American Aero Cranes & Water Blasting Systams P.O. Box 41249 Houston, TX 77241 713-896-2002	Water blasting equipment Wet abrasive blasting equipment

WATER AND WET ABRASIVE BLASTING EQUIPMENT AND SERVICES

Aqua-Dyne, Inc. 2208 Karbach Street Houston, TX 77092-8096 713-681-3581 800-231-9174 (USA) 800-392-4563 (TX OnlY)	Water blasting equipment Wet abrasive blasting equipment
Aquatel Industries, Inc. Marine Division 128 Alto Place Baltimore, MD 21227	Water blasting equipment
Aquatron International, Inc. 115 Enterprise Drive Gretna, LA 70053	Water blasting equipment
Arthur Products Company 618 East Smith Road Medina, OH 44256 216-725-4905	Water blasting nozzles
Astro Pak 8708 Cleta Street P.O. Box 978 Downey, CA 90241	Water blasting services
Blast-it-All, Inc. P.O. BOX 1615 Circle M Industrial. Park Highway 29 South Salisbury, NC 28145 704-636-8302 800-438-3854	Water blasting equipment Wet abrasive blasting equipment
Blasters, Inc. 7813 Professional Place Tampa, FL 33610	Water blasting equipment
Blume Worldwide Services 246 Marmaroneck Road Scarsdale, NY 10583 914-723-6185	Water blasting equiment

Broadfield Manufacturing Company Max Dreitzler & Sons Division George Street @ First Avenue Galien, MI 49113	High pessure parts washer
Browning Ferris Industries P.O. Box 3151 Houston, TX 77253 713-870-8100	Water blasting equipment Wet abrasive blasting equipment
Butterworth, Inc. P.O. Box 18312 3721 Lapas Drive Houston, TX 77223 800-231-3628 713-644-3636	Water blasting equipment
Cambridge Sandblast/Atrasives Broad Lane Cottenham, Cambridge, England UNITED KINGDOM 0954-51773	Water blasting equipment Wet abrasive blasting equipment
Cameng Services Limited 7504F 30 Street SE Calgary, AB T2C 1M8 CANADA 403-236-5590	Water blasting equipment
Cat Pumps Corporation 1681 94th Lane NE P.O. Drawer 885 Minneapolis, MN 55434	Wet abrasive blasting equipment
Ceda 230 - 6712 Fisher Street, SE Calgary, Alberta T2H 2A7 CANADA 403-253-3233	Water blasting services

WATER AND WET ABRASIVE BLASTING EQUIPMENT AND SERVICES

Cel Hydraulics, Inc. P.O. Box 9779 Finistere Court Atlanta, GA 30319 404-252-0757	Water blasting equipment Wet abrasive blasting equipment
Clemco Industries P.O. Box 7680 San Francisco, CA 94120 415-282-7290	Wet abrasive blasting equipment
Clemtex, Inc. P.O. Box 15214 Houston, TX 77020-5214 713-672-8251	Water blasting equipment Wet abrasive blasting equipment
Colman Manufacturing Company, Inc. 4904 16th Avenue South Tampa, FL 33610	Water blasting equipment
Combs Industrial & Machine Painters 509 Holt Avenue Mount Sterling, KY 40353	Water blasting services
Camser Corporation 15-100 Frederick Road Woodbine, MD 21797 301-442-1100	Water blasting equipment
Cormat International., Inc. P.O. Box 18167 Orlando, FL 32860-8167 305-849-7764	Water blasting equipment
Corotech, Inc 17181 Taft Street Spring Lake, MI 49456 616-846-7010	Water blasting services

R.L. Corty & Company 3704 North Cicero Avenue Chicago, IL 60641	Water blasting equipment
Del co Manufacturing Company, Inc. P.O. BOX 69 Siloam Springs, AR 72761 501-524-6471	Water blasting equipment Wet abrasive blasting equipment
Delong Equipment Company Department 2-A 2179 Ch. Bridge Road, NE Atlanta, GA 30324	Water blasting equipment
Eastern Cleaning Equipment company 440 North Elmwood Road P.O. Box 507 Marlton, NJ 08053 609-596-0096	Water blasting equipment Wet abrasive blasting equipment
Edwards Manufacturing Company 8217 SE McLaughlin Boulevard Portland, OR 97202	Water blasting equipment
Elliott Company P.O. Box 239 East 3240 National Road Springfield, CH 45501 513-3244191	Water blasting equipment
Euroclean Division The Kent Company P.O. Box 1665 Elkhart, IN 46515 219-293-8666	Water blasting equipment
Federal Industrial Services, Inc. 12980 Inkster Road Redford, MI 48239	Water blasting services

WATER AND WET ABRASIVE BLASTING EQUIPMENT AND SERVICES

Gelber Pumps, Inc. 3721 West Morse Avenue L incolnwood, IL 60645 312-673-5800	Water blasting equipment
Giant Products Company 3150 Bellevue Road Toledo, CH 43606	Wet abrasive blesting equipment
Larry Goad & Company, Inc. 626 Old State Road St. LouiS, MO 63011 314-394-6334	Wet abrasive blasting equipment
Gram, Inc. P.O. Box 1441 Minneapolis, MN 55440 612-623-6000	Water blasting equipment
Great Lakes Hydraulics, Inc. 4172 36th Street South Grand Rapids, MI 49508	Water blasting equipment
H & H Industrial P.O. Box 262 Wooster, CH 44691	Water blasting services
Halliburton Industrial Services P.O. Drawer 297 Duncan, OK 73536 405-251-3360	Water blasting services
Hsrben, Inc. Department 1 Route 10, 338, Box 163 Cumming, GA 30130 404-889-9535	Water blasting equipment Wet abrasive blasting equipment
Hartman-Walsh Painting Company 7144 North Market St. LouiS, MO 63133 314-863-1800	Water blasting services

Heavy Duty Hydro Blasting, Inc. 1360 West 53rd Street West Palm Beach, FL 33407 305-842-2338	Water blasting equipment Wet abrasive blassting equipment
C.H. Heist Corporation 600 Cleveland Clearwater, FL 33515	Water blasting services
Homestead Industries, Inc. Jenny Division II Johnson Street Coraopolis, PA 15108 412-771-2628	Water blasting equipment
Hydrair-America Company P.O. Box 1332 Roswell, GA 30077 404-476-4071	Wet abrasive blasting equipment
Hydroblaster, Inc. P.O. Box 2204 Watson Way Sparks, NV 89432 702-359-7752	Water blasting equipment
Hydro-Manufacturing P.O. Box 308 Missouri City, TX 77439-0308 800-231-6913 713-499-1666	Water blasting equipment
Hydrosander, Inc. 5617 Fairfield Road Columbia, SC 29203	Wet abrasive blasting equipment
Hydro-Silica Corporation 3444 Register Street Gasport, NY 14067	Wet abrasive blasting equipment

WATER AND WET ABRASIVE BLASTING EQUIPMENT AND SERVICES

Industrial. Enterprises, Inc. P.O. Drawer 156A Placerville, CA 95667	Water blasting equipment Wet abrasive blasting equipment
Industrial Innovations, Inc. P.O. Drawer 830 Stockton, CA 95201	Water blasting equipment
Industrial Pressure, Inc. P.O. BOX 1187 Harvey, LA 70059 504-368-0751	Water blasting equipment
International Tool & Abrasives, Inc. 493 Fort Johnson Avenue Bohemia, NY 11716	Water blasting equipment
Jet Blast Company 510 Monroe Street Hoboken, NJ 07030 201-656-1735	Water blasting equipment
Jetin Sullair 5131 NE Union Avenue Portland, OR 97211 503-249-8191	Water blasting equipment
Jupiter Engineering, Inc. P.O. Box 1666 138 Evernia Street Jupiter, FL 33458 305-746-3984	Wet abrasive blasting equipment
LCO Cleaning Systems, Inc. 2513 Warfield Street Fort Worth, TX 76106 817-625-4213	Water blasting equipment
Liquabrade P.O. Box 66222 Baton Rouge, LA 70896	Water blasting equipment

Mainstay Corporation P.O. Box 965 Roswell, GA 30136 404-476-4071	Water blasting equiment
MCM, Inc. 9722 South 550 West Lafsyette, IN 47905	Water blasting equipment
F.E. Myers Company 400 Orange Street Ashland, CH 44805	Water blasting equipment
National Liquid Blasting Corporation 29830 Ce Beck Road Wixom, MI 48096 313-624-5555	Water blasting equipment
Nor theast Industries, Inc. 301 Greenwood Avenue Midland Park, NJ 07432 201-652-6202	Water blasting equipment Wet abrasive blasting equipmnt
Pauli & Griffin Company 907 Cotting Lane Vacaville, CA 95688 707-447-7000	Wet abrasive blasting equipment
Bennington Brothers, Inc. 5300 Grand Haven Road Muskegon, MI 49441 616-798-2191	Water blasting services
Permashell Corporation Limited 33 Maplecrete Road Concord, CN L4K 1A5 CANADA 416-669-9606	Wet abrasive blasting equipment

WATER AND WET ABRASIVE BLASTING EQUIPMENT AND SERVICES

Pollution Control Services, Inc. Department 2-A 200 Industrial Parkway Chagrin Falls, CH 44022 216-247-5722	Water blasting services
Pressure Blast Manufacturing Co., Inc. 41 Chapel Street Manchester, CT 06040 203-643-2487	Wet blasting equipment
Progressive Blasting Systems 4201 Patterson SE Grand Rapids, MI 49508 616-957-0871	Wet abrasive blasting equipment
Pur-Tex, Division of Pursell Equipment Company, Inc. 3627 Crosby-Cedar Bayou Road Baytown, TX 77521 713-427-9481	Water blasting equipment
Ruemelin Manufacturing Company 3860 North Palmer Street Milwaukee, WI 53212 414-962-6500	Water blasting equipment
Sandstorm-Bow en Tools, Inc. P.O. Box 3186 Houston, TX 77012 713-869-2227	Water blasting equipment
Sealand Organization P.O. Drawer 7262 The Woodlands, TX 77387 713-367-4209	Water blasting equipment
Sherwin-Williams Company 101 Prospect Avenue NW Cleveland, CH 44101 216-566-3349	Water blasting equipment

Sioux Steam Cleaner Corporation Sioux Plaza Beresford, SD 57004 605-763-2776	Water blasting equipment
Southwest Abrasive & Equipment Company, Inc. 2665 Perth Street Dallas, TX 75220 214-350-5561	Water blasting equipment
Spartan Manufacturing Corporation Department S/L P.O. Box 917 Kernersville, NC 27284 919-996-5585	Wet abrasive blasting equipment
Spartan Tool Division, Helco, Inc. South 14th Avenue Mendota, IL 61342 815-539-7411	Water blasting equipment
Sprak Water Blasting Equipment, Inc. 411 South H Street Lake Worth, FL 33460 800-327-8530 305-585-1538	Water blasting equipment
Steele & Sons, Inc. P.O. Box 965 Roswell, GA 30136 314-771-8053	Water blasting services
Sullair Corporation 3700 East Michigan Boulevard Michigan City, IN 46360 219-879-5451	Water blasting equipment
Superior Sandblasting & Fabricating Company, Inc. 5645 Manchester Avenue St. LouiS, MO 63110 314-645-5561	Water blasting equipment

Thunderbird Industries, Inc. P.O. Box 959 Noble, OK 73068 405-364-8854, Ext. 100	Water blasting equipment
Tritan Corporation P.O. Box 12333 9000 Airport Boulevard Houston, TX 77217-2333 713-941-8941	Water blasting equipment Wet abrasive blasting equipment
Ultrajet P.O. Drawer 693 Mill Vslley, CA 94942 415-383-5790	Water blasting equipment
Universal Nozzle Company Universal Turret Nozzle P.O. Box 477 Dixon, MO 65459	Water blasting equipment
Vapor Blast Manufacturing Company 3019 West Atkinson Avenue Milwaukee, WI 53209 414-871-6500	Water blasting equipment Wet abrasive blasting equipment
Versailles, Inc. 139 Montresl East Blvd. Montreal East, PQ H1B 5P1 CANADA 514-645-2216	Water blasting services
Vicjet, Inc. 212 Sunset Road Strafford, PA 19087 215-688-7550	Water blasting equipment
Wagner Spray Technical Corporation 1770 Ferbrook Lane Minneapolis, MN 55441 612-559-1770	Water blasting equipment

Weatherford P.O. Box 41249 Houston, TX 77241 800-231-3556 713-896-0002	Water blasting equipment Wet abrasive blasting equipment
Williams Contracting, Inc. 2076 West Park Place Stone Mountain, GA 30087 404-498-2020	Wet abrasive blasting equipment Wet abrasive blasting services
Wilson & Hampton Painting Contractors 1524 Mable Street Anaheim, CA 92802 714-772-5091	Water blasting services
Woma Corporation 242 St. Nicholas Avenue South Plainfield, NJ 07080 201-753-0001	Water blasting equipment Wet abrasive bl asting equipment
Zero Manufacturing Company 811 Duncan Avenue Washington, MO 63090 314-239-6721	Wet abrasive blasting equipment

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APPENDIX C

TESTS AND DATA FROM OTHER SOURCES

C.1 FLORIDA DEPARTMENT OF TRANSFORMATION TEST RESULTS

C.2 TEXAS HIGHWAY DEPARTMENT TEST RESULTS

C.3 ROYAL ENGINEERS TECHNICAL SERVICE TEST RESULTS

C.4 INDUSTRIAL TEST RESULTS (SHIPPING OWNER)

C.5 MANUFACTURER'S DATA (CLEMTEX)

C.6 MANUFACTURER's DATA (HYDRAIA)

C.7 MANUFACTURER'S DATA (LIQUABRADE)

C.8 MANUFACTURER's DATA (BUTTERWORTH)

TABLE C-1

FLORIDA DEPARTMENT OF TRANSFORMATION TEST RESULTS

	High Pressure[a] Water Blast	Air Sand[b] Wet Blast	Dry Sand Blast
Air Pressure (psi)	-----	80-90	80-90
Nozzle Dia. (inch)	----	3/8	3/8
Water Pressure (psi)	2500	-----	----
Flow Rate (gpm)	4[c]	o.16[c,d]	-----
SUBSTRATE		OIL-BASED PAINT, 10-15% RUSTED	
Final Condition	SSPC-SP 7	SSPC-SP 7	SSPC-SP 7
Cleaning Rate (sq. ft./hr)	85	380	450
Sand Consumption (lbs./sq. ft.)	0	2	1.7
Est. Cost/sq. ft.	$0.46	$0.13	$0.11
Final Condition	-----	SSPC-SP 6	SSPC-SP 6
Cleaning Rate (sq. ft./hr.)	-----	180	210
Sand Consumption (lbs./sq.ft.)	-----	4.3	3.7
Est. Cost/sq. ft.[e]	-----	$0.28	$0.23
Final Condition	----	SSPC-SP 10	SSPC-SP 10
Cleaning Rate (sq. ft./hr.)	-----	90	120
Sand Consumption (lbs./sq/ ft.)	-----	8.8	6.4
Est. Cost/sq. ft.[e]	-----	$0.56	$0.40

NOTES:

a - Simpson Water Blast Unit PG4-1500 with Graco "King" hydraulic pump
b - Water was sprayed into dry blast beyond the nozzle
c - Inhibitor used was 0.3 $NsNO_2$, 13% $(NH_4)_2HPO_4$
d - At flow rates of 0.25 gpm, sand caked up on beam
e - Cost includes equipment rental, labor, fuel, inhibitor, abrasive, and water
f - Air particulate matter samples obtained 25 yards downwind from operations were as follows:
- O dry blast: 525 to 800 micrograms/m^3 averaged over 24 hours
- O wet blast: 146 to 322 micrograms/m^3 averaged over 24 hours

REFERENCE:

Final Report, Florida Dept. of Transportation, Basic Agreement No. DOT-FH-11-8591, Federal Highway Administration (FHWA) Task Order No. 1: "Evaluation of Commercial Blast Cleaning Methods," June 1980: B.R. Ramsey and J.D. Roberts

TABLE C-2

TEXAS HIGHWAY DEPARTMENT TEST RESULTS

	High Pressme Water Blasting	Pressurized Water/Abrasive Blast	Dry Sand Blast
Water Pressure (psi)	9000	9500	-----
Flow Rate (gpm)	4	4	-----
SUBSTRATE	PREVIOUSLY PAINTED STEEL BEAMS (SOME DETERIORATION)		
Final Condition	SSPC-SP 10	SSPC-SP 10	SSPC-SP 10
Cleaning Rate (sq. ft./hr.)	25	150	345
Sand Consumption (lbs/sqo ft.)	0	2.7	8

NOTES:

a - EQuipment was Model 61O-D diesel 35 hp pump, water discharge hs 1/4" ID, Z100 Abrasa-Blast sand nozzle.
b - Dry blasting equipment was 750 C FM compressor, 8 nozzle (1/2 inch), 50 ft of l-1/2" sand hose.
c - Inhibitor used was 8 cups sodium nitrite, 1 pint isoyopyl alcohol in 5 gallons of water, consumption rate was 3 gallons per hour.
d - Clean-up required use of compressed air to dry wet sand.

REFERENCE:

Final Report (N-518-1F), FHWA Contract DOT-FH-11-8608 task order No. 16, (FCIP Study 1-10-79-508), "Evaluation of Commercial Blast Cleaning Systems," 1980, J. Underwood.

TABLE C-3

ROYAL ENGINEERS TECHNICAL SERVICE TEST RESULTS[e]

	Pressurized Water Abrasive[a]	Pressurized Water Abrasive[b]	Dry Grit
Water Pressure (psi)	4,000	7,000	-----
Flow Rate (gpm)	-----	15	----
SUBSTRATE: PAINT TOPCOAT AND METALLIC ZINC (FLAME SPRAYED) ON PIER BEAM			
Area Cleaned (Sq. ft.)	4.5	4.5	1
Final Condition	99% removal	complete removel	complete removal
Cleaning Rate (sq. ft./hr.)	18	-40	10
Sand Consumption (lbs./sq.ft.)	-----	26	----

NOTES:

a - Harben 4008 used for 4000 psi
b - Harben DS 150 used for 7000 psi
c - Used both alumina and sand as abrasives
e - Dry blast evaluation conducted on different project
f - Data were not corroborated by SSPC

REFERENCE:

"Refurbishment by High pressure Water with Abrasive: Part 1, Initial Triels Comparison of Processes; Part 2, Confirmatory Wet Blast Trials," December, 1984, S/SGT. M.E. Pearson, Royal Engineers Technical Service, The Barracks, Barracks Road, Christchurch, Dorset, BH23 2BB, United Kingdom.

TABLE C-4

INDUSTRIAL TEST RESULTS (SHIPPING OWNER)[f]

	High Fressure Water Jetting[a]	Pressurized Water Sand[a]	Pressurized Water Sand[a]	Manual Scraping
Water Pres. (psi)	10,000	10,000	10,000	-----
Flow Rate (gpm)	10	10	10	-----
SUBSTRATE[b]	12-50% RUST	12% RUST	75% RUST	50% RUST
Final Condition	SSPC-SP 7	SSPC-SP 10	SSPC-SP 10	SSP-SP 2
Cleaning Rate[c] (sq. ft./hr)	145	120[d,e]	70[d]	39
Cleaning Rate[e] (sq. ft./day)	870	640	380	270
Sand Cons. Rate (lbs./sq. ft.)	0	0.9	1.1	0

NOTES:

a - Partek Liqua-Blaster
b - Painted Steal. with varying degrees of rusting
c - Includes time for equipment set-up, rinsing and application of one coat of primer, assumes 6-hour workday
d - Includes time for Preliminary blast with high-pressure water without sand to remove loose material
e - Pressure drop to 9,000 psi resulted in a 10-15% reduction in cleaning rate
f - Data were not corroborated by SSPC

REFERENCE:

Private Communication.

TABLE C-5

MANUFACTURER'S DATA

Location: Oil Company Tank Farm, Gulf Coast
Date: August 9, 1982
Surface Condition: Pitted Rust

Weather: Cloudy, S. E. Wind 8-10 mph
Humidity: 80%

TEST NO.	TYPE EQUIPMENT USED	ABRASIVE TYPE	AMOUNT OF DUST CREATED	SQ. FT. CLEANED	TIME INVOLVED (MINUTES)	AMOUNT OF ABRASIVE USED	AMOUNT WATEP USED (gal.)	SURFACE CONDITION CONDITION	SQ. FT./ HOUR	ABRASIVE CONSUMP. (LBS/SQ. FT.)	COMMENTS
1	Dry Sandblast w/3/8" Venturi 90-100 psi nozzle pressure	16/40 mesh sand	Dusty	45	15	200 lbs	None	SSPC-SP 10 NACE-2 Near-White	180	4.5	Dusty Operation - May Be Offensive - Most Economical
2.	Dry Sandblast w/Wet Blast Attachment (ring) 3/8" on nozzle. 90 psi nozzle pressure	16/40 mesh sand	Minimal - 85% of Dust Contained	42	15	200 lbs	30	SSPC-SP 10 NACE-2 Near-White	168	4.8	Contains Dust - Least Costly Method of Wet Blasting
3.	Air/Water/Sand Slurry Blast with 3/8" nozzle. 100 psi pressure.	16/40 mesh sand	None	25	10	150 lbs	50	SSPC-SP 10 NACE-2 Near-White	150	6.0	Contains Dust - Abrasive Flow Erratic - Slow Cleaning
4.	High Pressure Water/ Sand Blast; 6,000 - 7,000 psi	16/40 mesh sand	None	40	15	300 lbs	120	SSPC-SP 10 NACE-2 Near-White	160	7.5	Contains Dust - Abrasive Consumption High - High Fatigue Factor
5.	Air Abrasive Wet Blaster at 90 psi nozzle pressure	16/40 mesh sand	None	48	15	200 lbs	15	SSPC-SP 10 NACE-2 Near-White	192	4.2	Contains Dust - Most Efficient Method of Wet Blasting

** Note: Wet blast operations require the surface be washed down to remove spent abrasive and allowed to dry before coating is applied. If an inhibitor is used, large areas may be cleaned, left uncoated until entire surface is cleaned; then the entire surface must be washed clean and allowed to dry before coating.

Above data were not corroborated by SSPC.

Reference: Clemtex letter of October 19, 1982

TABLE C-6

MANUFACTURER 'S DATA (HYDRAIR)[c]

	Pressurized Water/Sand B lasting[a]	Dry Sand Blasting[b]
SUBSTRATE	EXTREMEL Y RUSTED STRUCTURAL STEEL	
Final Condition	White Metal"	"White Mstal"
Cleaning Rate (sq. ft. /hr.)	150	140
SUBSTRATE	LIGHT RUST AND MILL SCALE	
Final Condition	White Metal"	White Metal"
Cleaning Rate (sq. ft./hr.)	190	160
Sand Consumption (lbs./sq.ft.)	8	10

NOTES:

a - Hydro Sand Blaster, 8,000 psi, 13 gpm water
b - 110 psi, 3/8" nozzle
c - Data were not corroborated by SSPC

REFERIUICE:

Product Literature from Hydro Manufacturing

TABLE C-7

MANUFACTURER'S DATA (LIQUABARADE)[c]

	Air/Water/Sand Slurry Blast[a]	Dry Sand Blast[b]
Air Pressure (psi)	100	100
Nozzle Dia. (inch)	1/2	1/2
SUBSTRATE A	2 COATS RED OXIDE PRIMER, SOME CORROSION	
Final Condition	SSPC-SP 7	SSPC-SP 7
Cleaning Rate (sq. ft./hr.)	175	120
Sand Consumption (lbs./sq. ft.)	2.3	1.3
SUBSTRATE B	RUSTED MILL SCALE, RUST GRADE B	
Final Condition	SSPC-SP 5	SSPC-SP 10
Cleaning Rate (sq. ft./hr.)	90	80
Sand Consumption (lbs./sq. ft.)	7.5	11.6

NOTES:

a - Liquabrader (Liquadapt FTL-1 + Clemco SCW 2040 dry blast pot), flow rate 0.3 GPM
b - Clemco SCW 2040 dry blast pot, 40/60 mesh sand
c - Data were not corroborated by SSPC.

REFERENCE:

Product Literature on Pro-Tech Liquabrade from PAL Services, Inc.

TABLE C-8

MANUFACTURER'S DATA #4

EQUIPMENT	SURFACE CONDITION (STEEL) (A) Overall Rust With Heavy Pitting	(B) Loose Mill Scale, Fine Rust, No Pitting	(C) Tight Mill Scale Little or No Rust	(D) Tight Paint, Negligible Rust
	SQUARE FEET BLASTED PER HOUR TO WHITE METAL			
High Pressure Water Sand Blast 10,000 psi @ 10 GPM. 300 lb pressurized sand tank.	120[1]	240[1]	245[1]	250[1]
Sand Consumption:	6 lbs/sq. ft.	3 lbs/sq. ft.	3 lbs/sq. ft.	3 lbs/sq. ft.
100 psi continuous dry blaster, 3/8" nozzle 240 cfm air compressor.	57[2]	216[2]	168[2]	n/a
Sand Consumption:	23 lbs/sq. ft.	6 lbs/sq. ft.	9 lbs/sq. ft.	n/a

1) Based on actual tests. (NOTE: differences in surface conditions, operator technique, etc. can result in variations in performance. No performance guarantees are implied.)

2) Based on rates from Table 3 of National Association of Corrosion Engineers' publication "Industrial Maintenance Painting", 3rd edition.

NOTE: Above data were not corroborated by SSPC.

REF: Product literature from Partek, Inc. (now Butterworth, Inc.)

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APPENDIX D

ACKNOWLEDGEMENTS AND SOURCES OF INFORMATION

The following organizations have participated in the field demonstrations described in Appendix A:

- Aqus-Dyne
- Butterworth, Incorporated
- Clemco, Incorporated
- Clemtex, Incorporated
- Exxon company, U.S.A.
- Hydrair
- Hydrosander, Incorporated
- Louisiana Department of Transportation and Development
- Monsanto Company
- Service Painting Company
- Weatherford, Incorporated
- Williams Contracting

In addition, the following organizations have furnished material used in the prepartion of the report:

- Add-Mach, Incorporated
- American Aero
- Cat Pumps Corporation
- Eastern Chemical Equipment Company
- Delco Manufacturing Company
- Edwards Manufacturing company
- Flow Industries, Incorporated
- Graco, Incorporated
- Harben, Incorporated
- Hydro Manufacturing and Sales
- Hydroblasters, Incorporated
- Jet Blast Company
- Liqua-Brade, Incorporated
- Midwest Research Institute
- National Association of Corrosion Engineers
- NLB Corporation
- Northeast Industries, Incorporated
- Royal Engineers Technical Service
- Seco, Incorporated
- Spartan Tool, Division HEICO, Inc.

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